



Machining excellence in small-batch production.

Unlocking hidden productivity in small-batch machining.



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Flow of the presentation

- Introduction
- Production excellence
- Machining process model
- Machining economics
- Economic machining
- Beyond economic machining
- The role of people
- Conclusions and summary



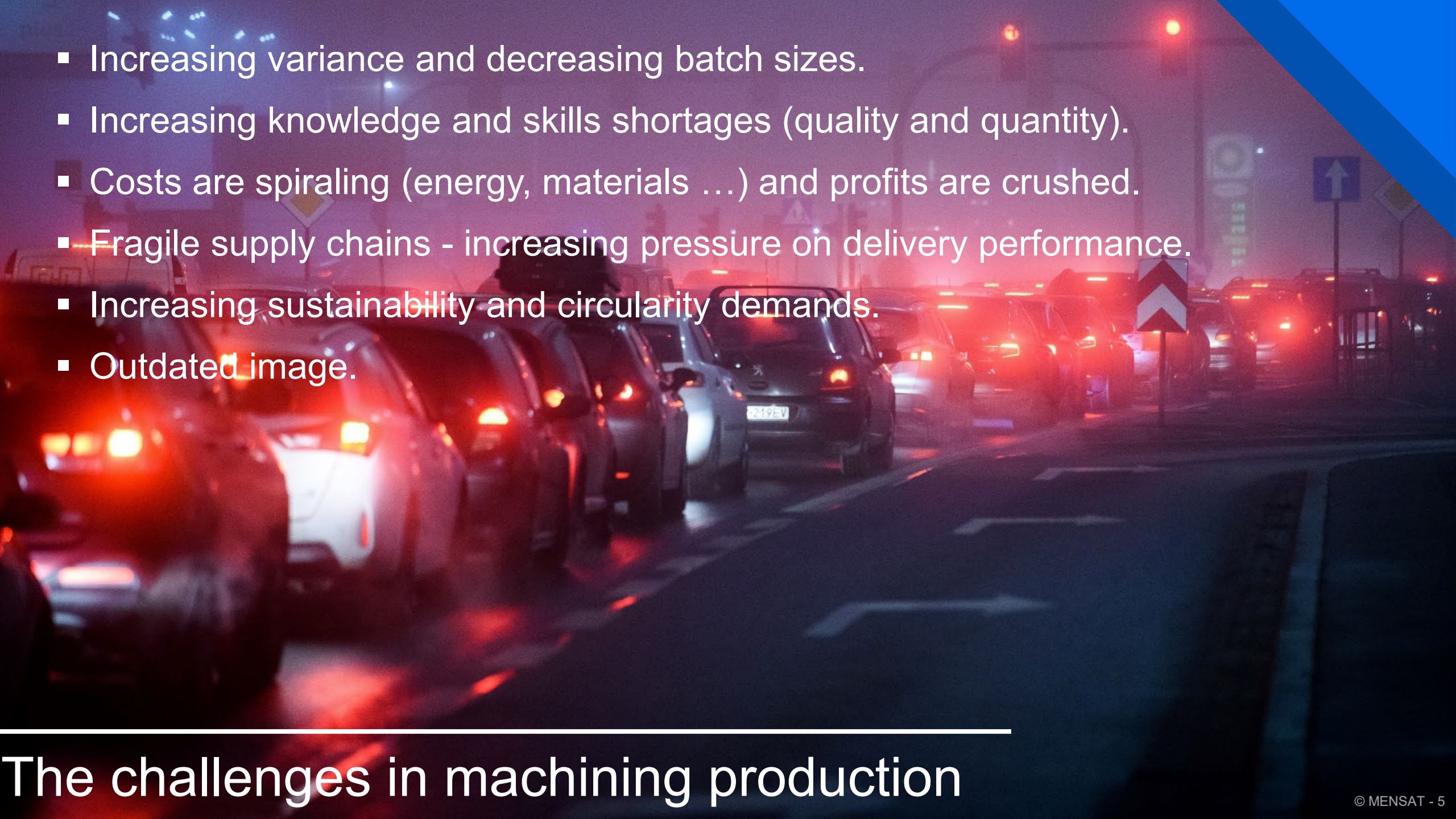
What's going on?

The machining industry is **shifting from mass production to small-batch, high-quality production**. Traditional approaches to select machining strategies, cutting tools and machining data, ... which are heavily related to high-volume production, are often inadequate in this new environment.

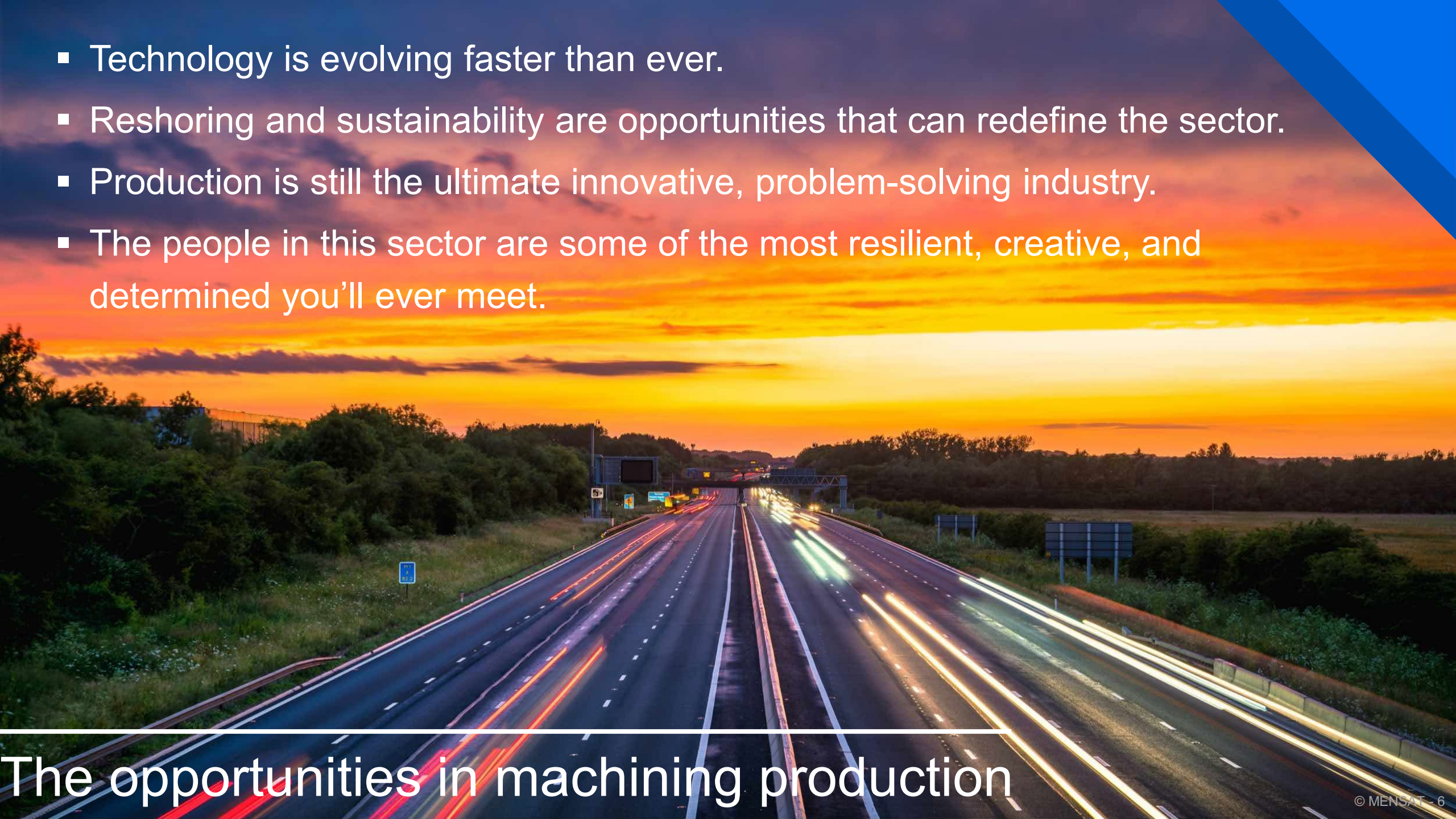
Companies must now focus on **process reliability, first-pass success, total production efficiency ...** rather than just cycle time optimisation.

Companies need new structured methods and capable people to make effective decisions in small-batch production.



- 
- Increasing variance and decreasing batch sizes.
 - Increasing knowledge and skills shortages (quality and quantity).
 - Costs are spiraling (energy, materials ...) and profits are crushed.
 - Fragile supply chains - increasing pressure on delivery performance.
 - Increasing sustainability and circularity demands.
 - Outdated image.

The challenges in machining production

- 
- Technology is evolving faster than ever.
 - Reshoring and sustainability are opportunities that can redefine the sector.
 - Production is still the ultimate innovative, problem-solving industry.
 - The people in this sector are some of the most resilient, creative, and determined you'll ever meet.

The opportunities in machining production

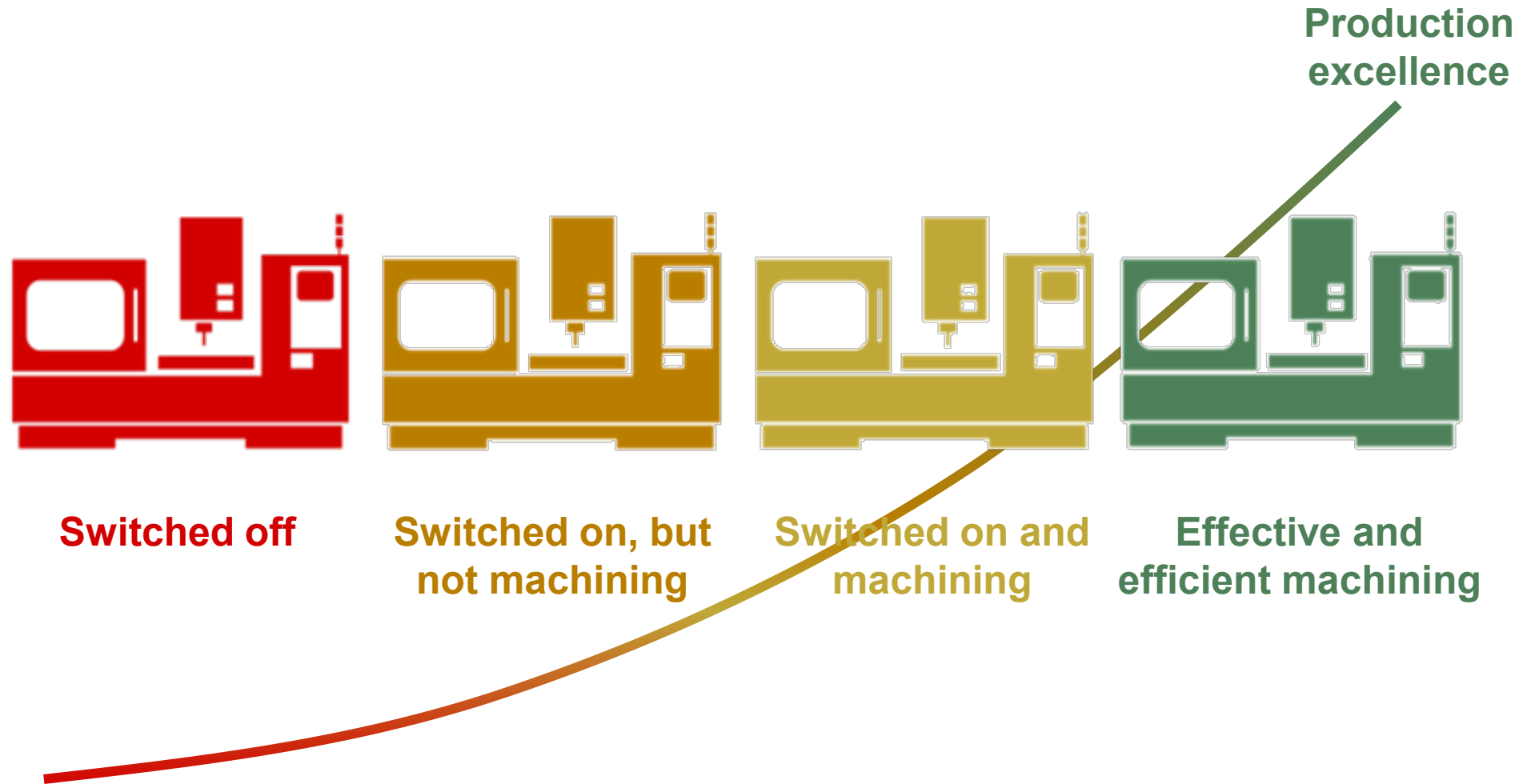
Production excellence

Production excellence is the sustainable and continuous improvement of operations and processes to gain a competitive edge over the competition through increased productivity and efficiency, lower costs and increased profits.

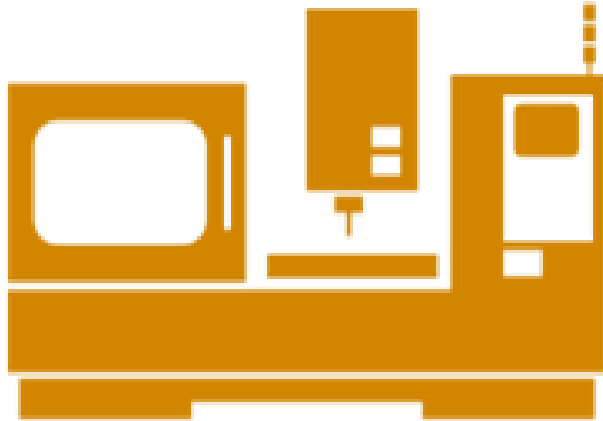
Production excellence is only possible when each employee can see the flow of value creation to the customer, and fix that flow when it breaks down.



Production excellence



Production excellence



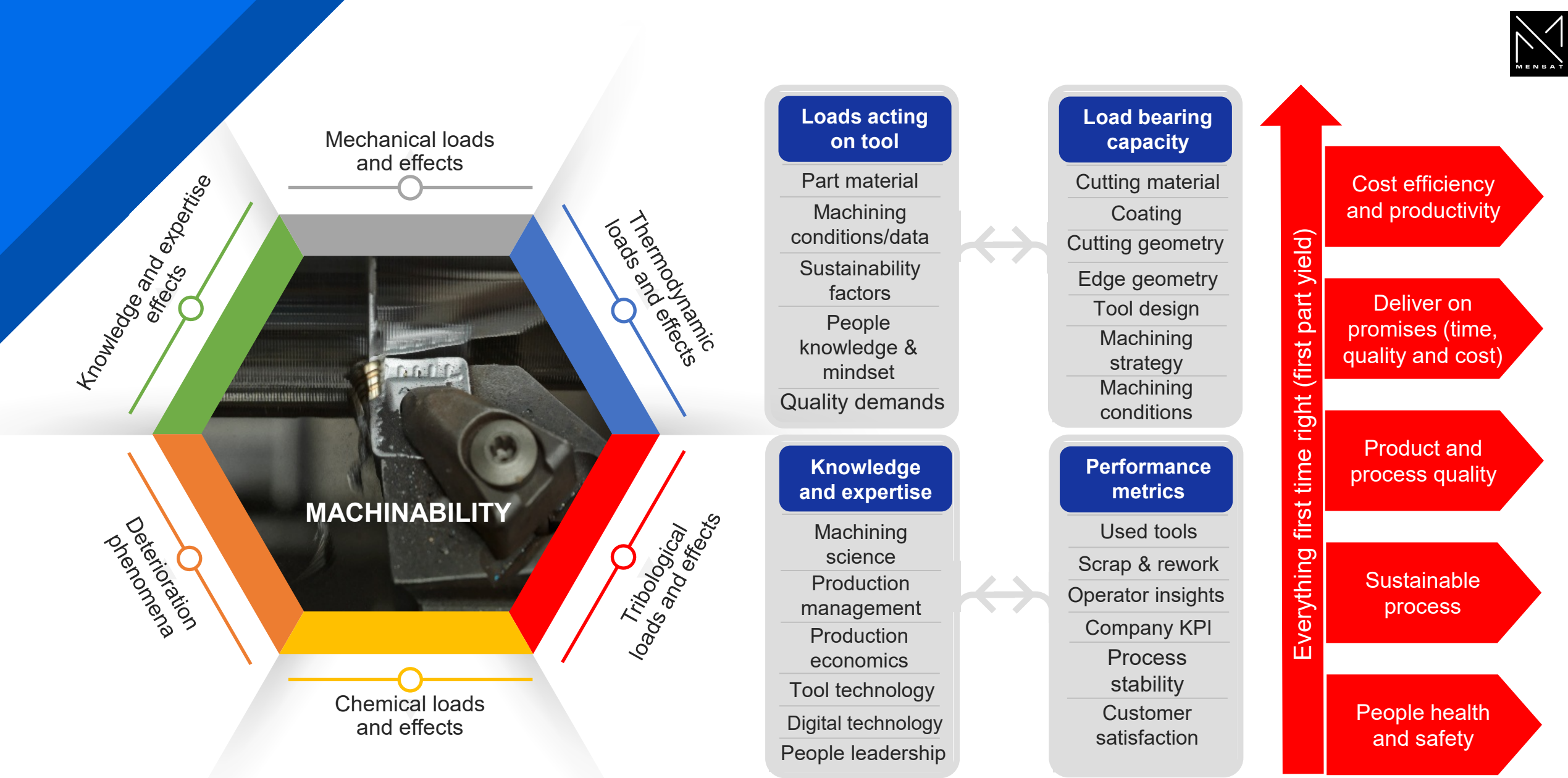
Machine is powered but not machining

- Set-up
- Workpiece manipulation
- Tool indexing/presetting
- Problem handling

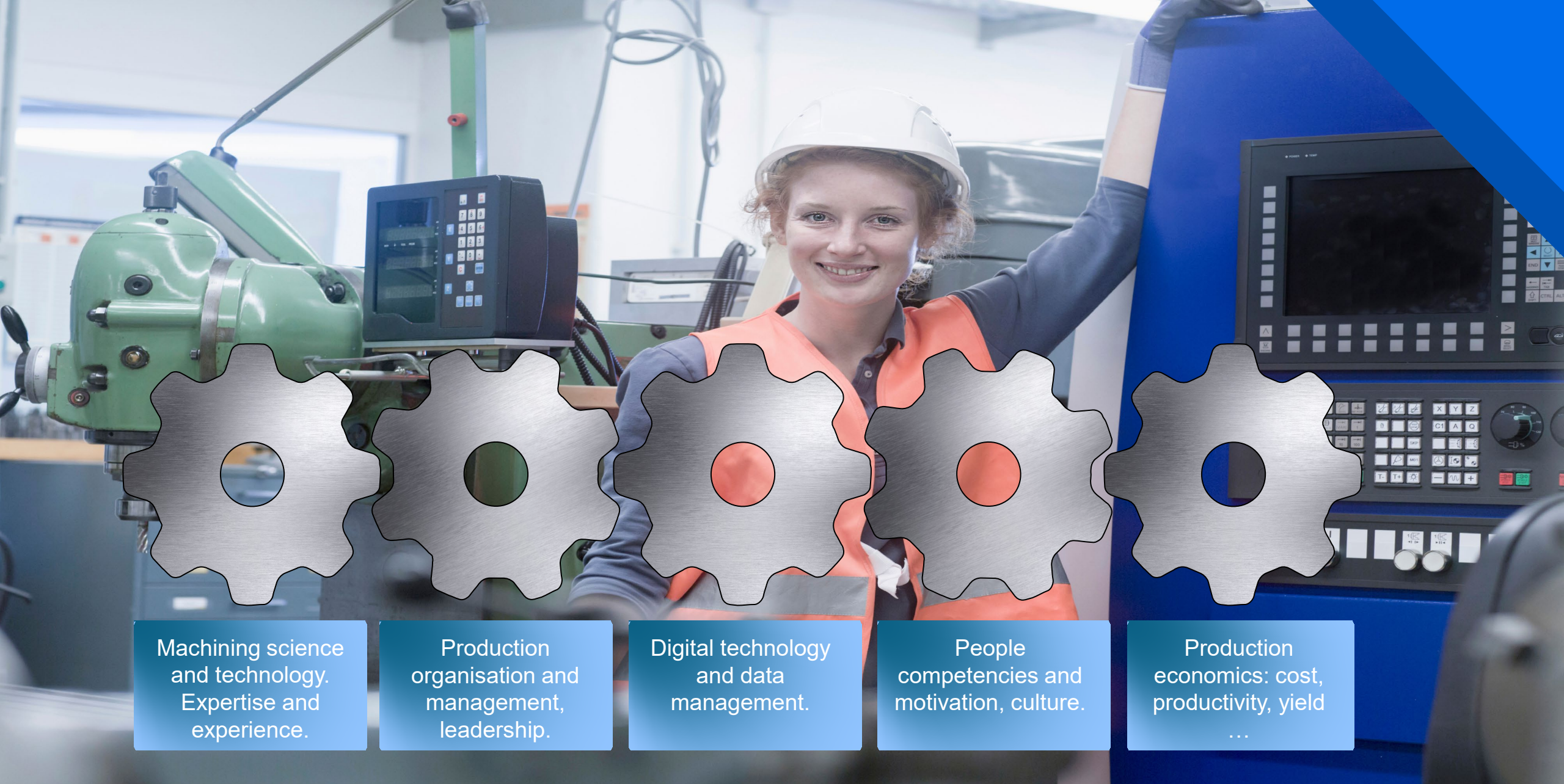


Machine is not efficient machining

- Not well selected tools
- Non-adapted or optimised strategies
- Unbalanced cutting data
- Out of scope cutting conditions



MENSAT machining process concept



Machining science
and technology.
Expertise and
experience.

Production
organisation and
management,
leadership.

Digital technology
and data
management.

People
competencies and
motivation, culture.

Production
economics: cost,
productivity, yield
...

Machining – knowledge & expertise domains



Machining process
applied physics &
technology

Knowledge on the
machining physics



Insight in the
practical process
- expertise



Skills on tooling
technology

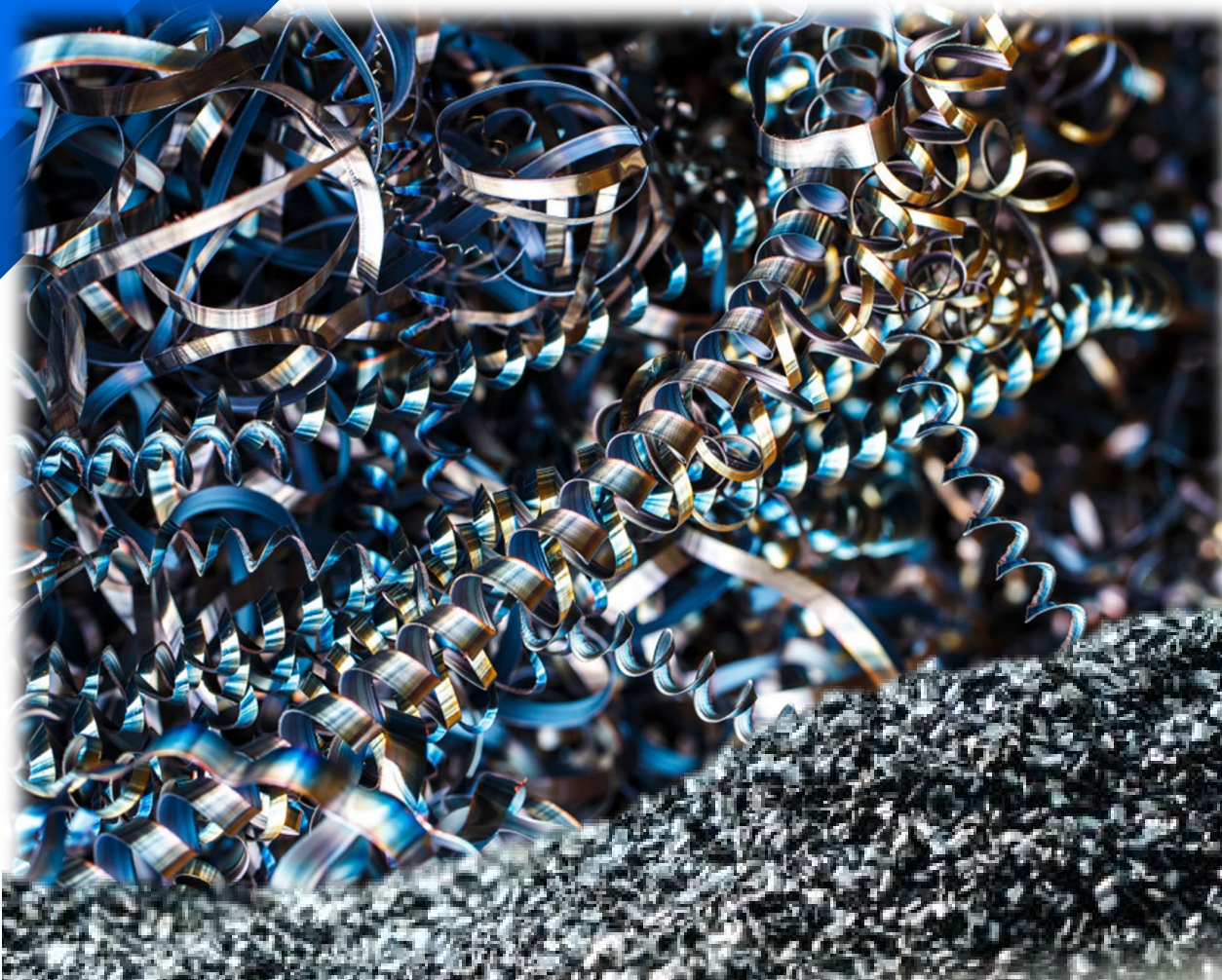


General
production
experience

**Chaos in
production &
process**

MENSAT machining process concept

GCFA



GTDA



MENSAT unique analysis methods & tools

Excellence in machining production depends **on the harmony between strategy, tooling, machining conditions, and the people behind the process.** These four elements are tightly connected; each influencing and shaping the others. The machining engineer's expertise determines the right starting point and ensures the loop is complete, while continuous feedback from the operator keeps the entire system optimised and alive.

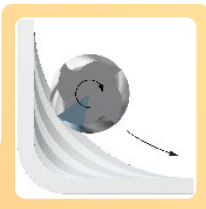


Production excellence



Machining Strategy

Productive, cost-efficient, stable and reliable, sustainable ...



Machining conditions

Machining environment, system, pre-conditions, data ...



Tooling

Performant, cost-efficient, reliable and predictable, versatile ...



Machining people

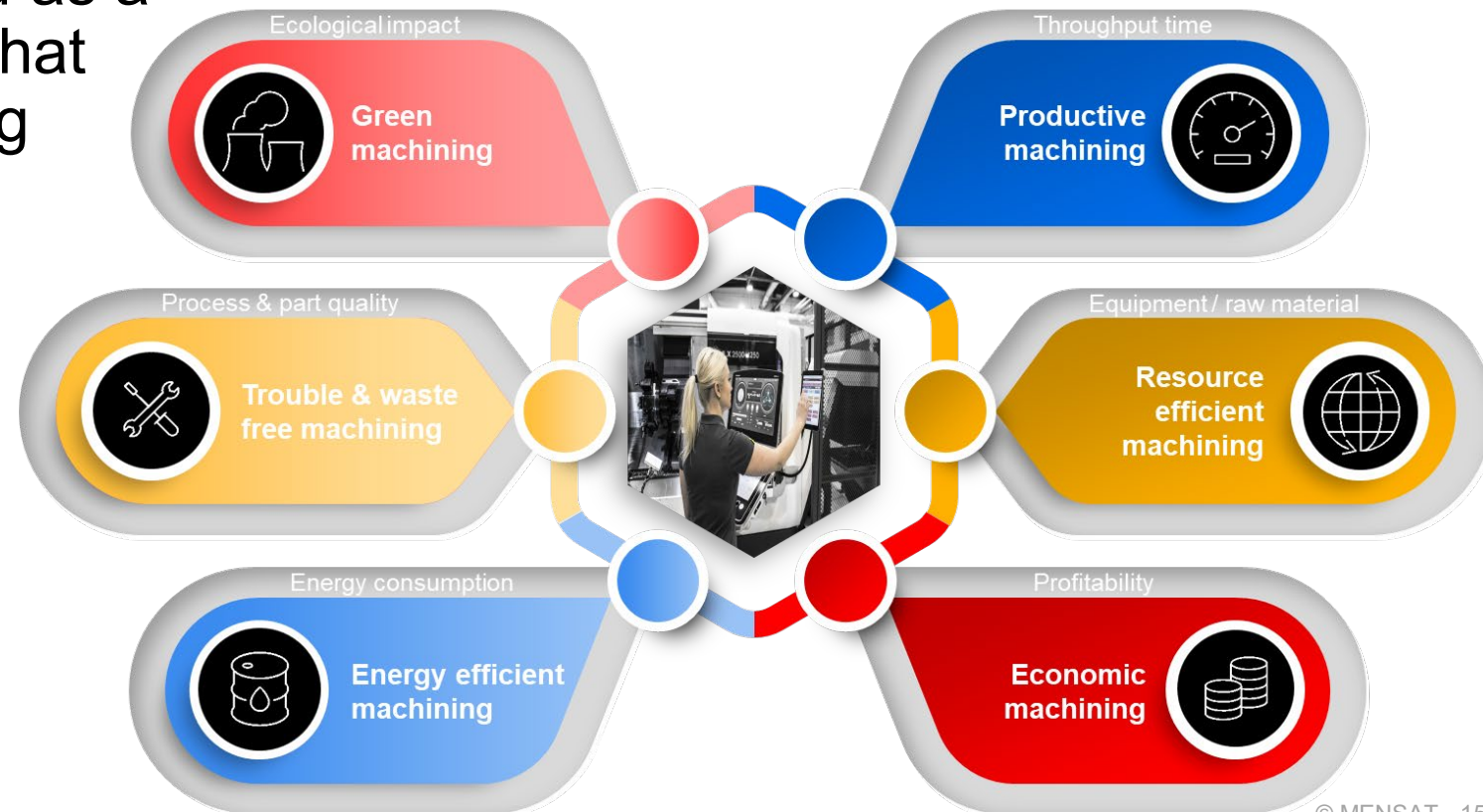
Knowledge, skills and expertise, motivation and mindset, ...

Machining economics

The term machining economics is applied to a series of optimisation scenarios associated with machining processes.

Like with all optimisation scenarios, it is important to define a criterion that can be either minimised or maximised as a function of factors and variables that can be controlled in the machining process and system.

An important consideration is about how narrow or wide the domain of factors and variables is defined.



Sustainability is about matching the needs of the present generation without compromising those of future generations.

- economic sustainability
- social sustainability
- moral & ethic sustainability
- trade & geopolitical sustainability
- resource and energy efficiency
- ecological sustainability



Sustainable machining

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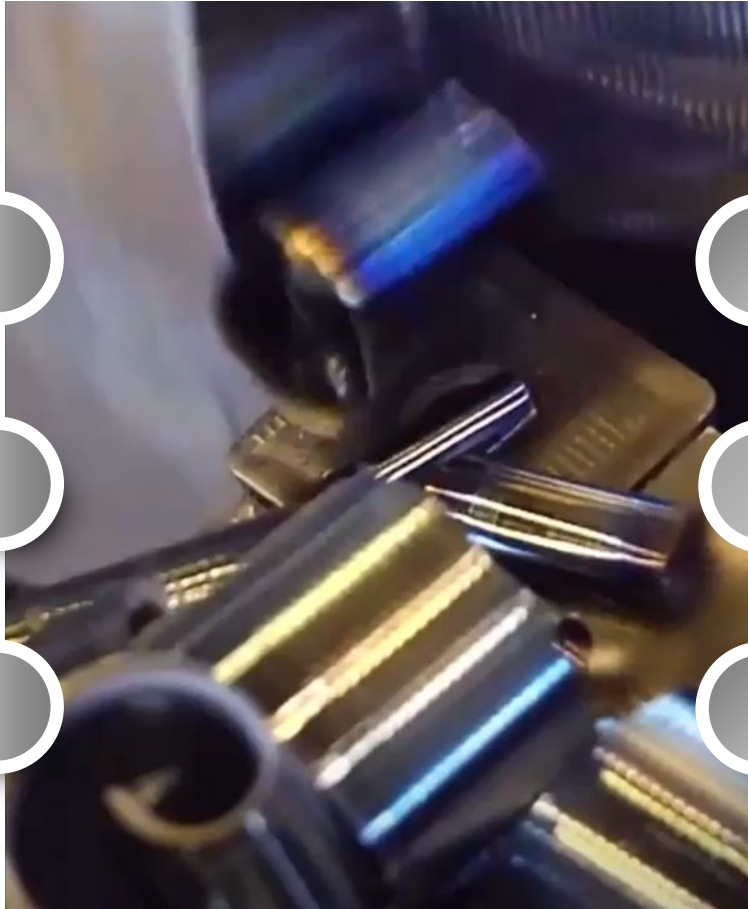
Economic machining



Mechanical loads
and effects

Thermodynamic
loads and effects

Tribological loads
and effects



Chemical loads
and effects

Deterioration
phenomena

Human impact
and effects

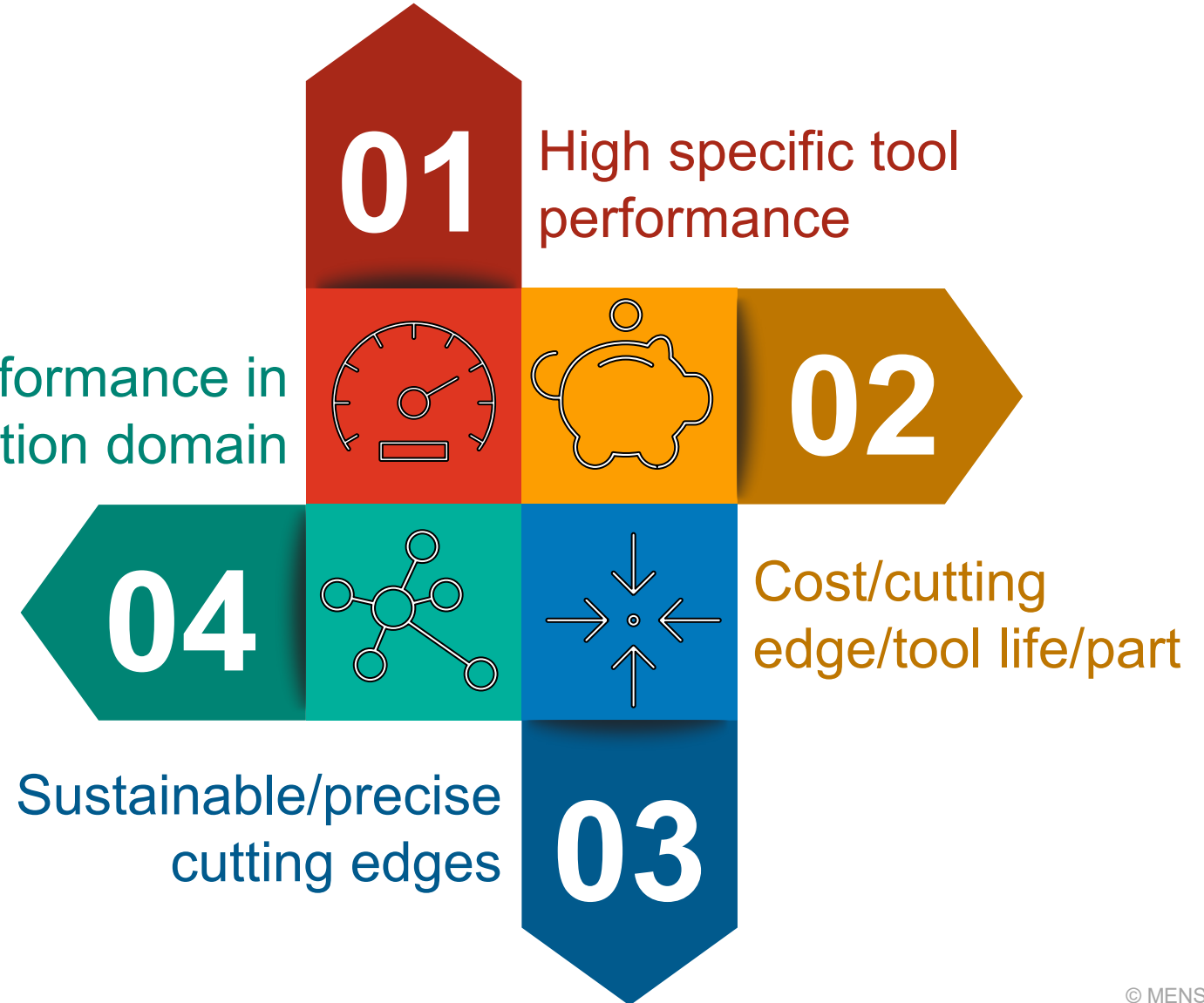
Physical description machining model



Tool selection in sync with company KPI

1. Productivity (time efficient)
2. Economy (cost efficiency, profit)
3. Quality of part output
4. Flexibility & versatility

Tool performance in
broad application domain





- Geometrical strategies
 - Linear, circular, trochoidal ...
 - Entry and exit strategy
- Tooling strategies
 - Face milling, square shoulder ...
- Technological strategies
 - High speed, high feed ...
- Sustainability strategies
 - Economical, productivity, reliability
 - First-time-right
 - Resource and energy efficient



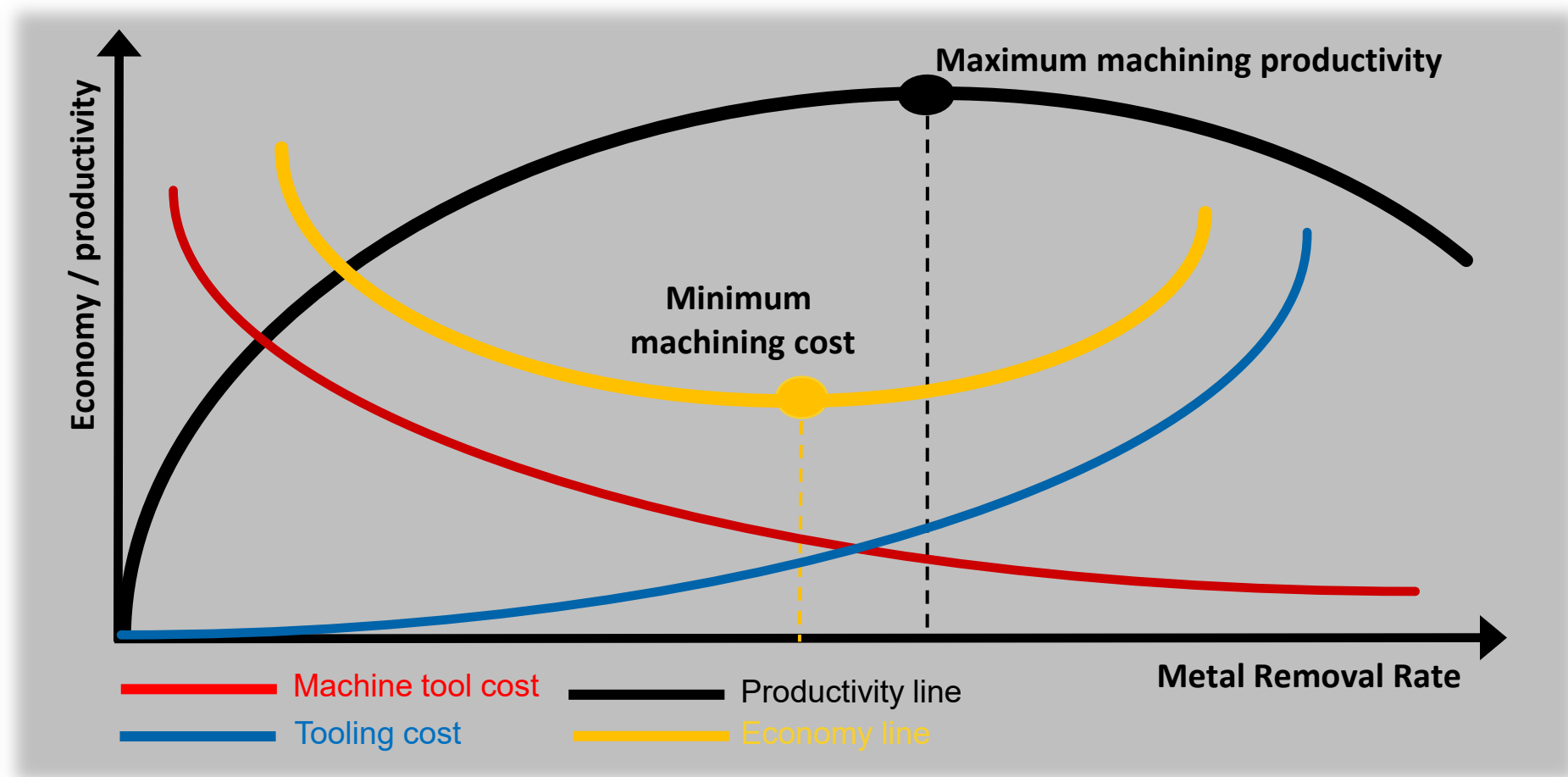
Machining strategies



Constraints due to

1. Chip formation and evacuation
2. Mechanical loads on the cutting edge
3. Thermodynamic loads on the cutting edge
4. Tribological loads on the cutting edge
5. Chemical loads on the cutting edge
6. Quality of machined surface demands
7. Resource and energy efficiency
8. Minimum waste and environment impact

Machining data window for trouble-free machining



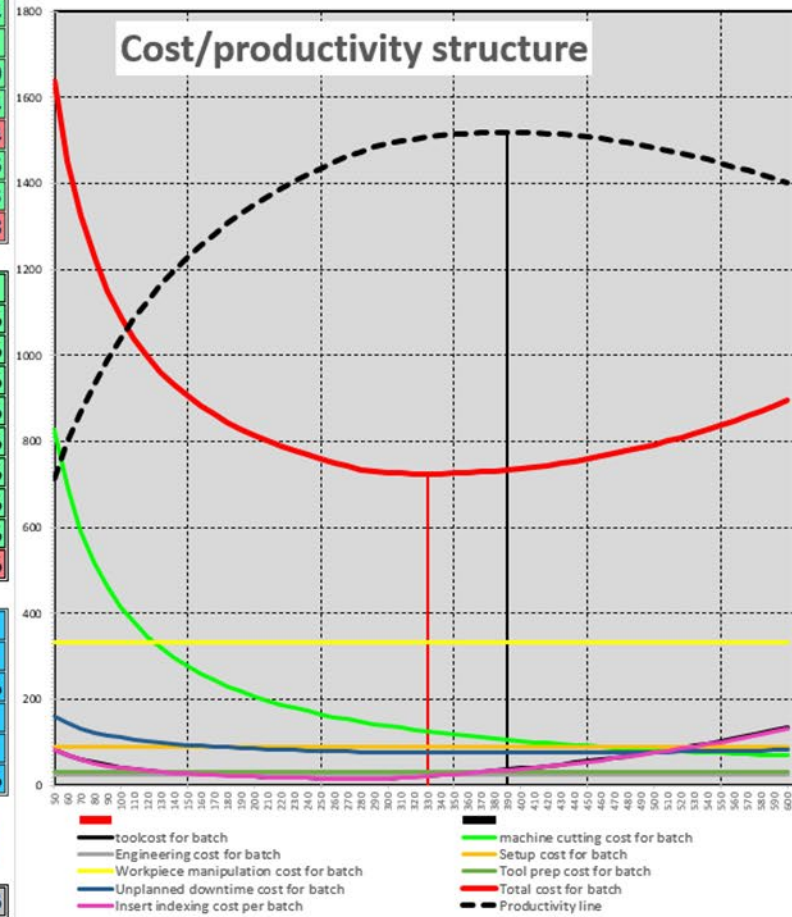
$$\text{Metal Removal Rate (MMR)} = a_p \times f \times v_c$$

Techno – economic model

Scenarios for economic machining

NEXT STEP Global Productivity and Cost Simulation Milling

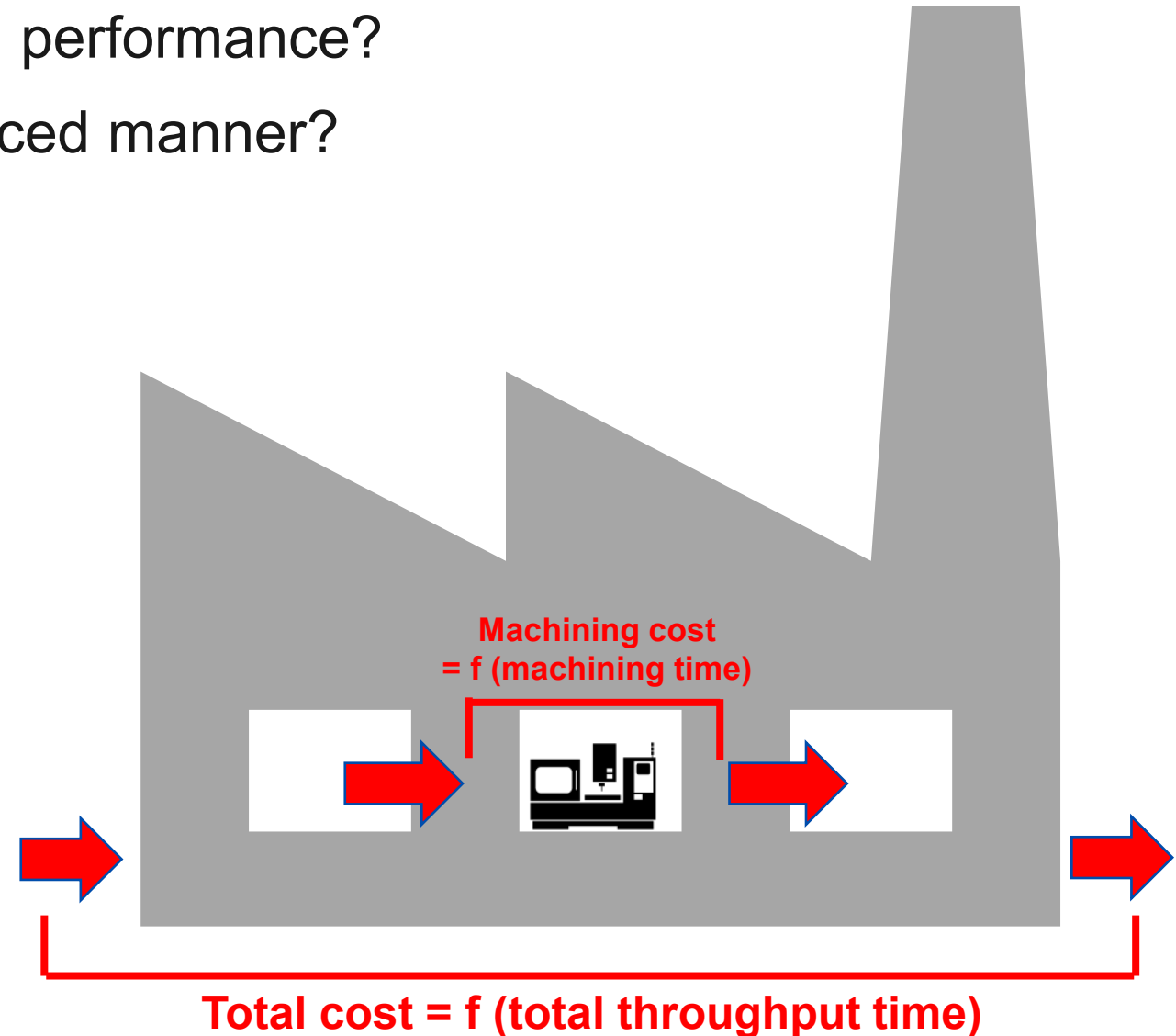
Machine tool		Maximum cutting speed due to power limits		1354	
Machine tool cost (\$/h)	75	Minimum cost		Maximum production	
Salary cost operator (\$/h)	15	Cutting speed	330	Cutting speed	390
Effective power (kW)	15	Tool life	144	Tool life	74
Engineering		Cost for batch	725	Cost for batch	734
Engineering cost (\$/h)	25	Cost per produced part	65	Cost per produced part	66
Cutting tool		Cost per OQD part	72	Cost per OQD part	73
Milling cutter cost (\$)	500	Production time for batch	512	Production time for batch	508
Arbor cost (\$)	250	Cost and time split			
Insert cost (\$)	15	Machine/salary cutting cost	17%	Machine/salary cutting cost	15%
Diameter cutter (mm)	32	Tooling cost	3%	Tooling cost	5%
Cutting edge angle (Kr)	90	Eng/set-up/toolprep cost	20%	Eng/set-up/toolprep cost	20%
Nbr of teeth	5	Workpiece/insert handling cost	49%	Workpiece/insert handling cost	50%
Nbr of cut edges/insert	2	Unplanned downtime cost	11%	Unplanned downtime cost	10%
Workpiece material	P4	Machining time	16%	Machining time	14%
Max allowed wear (mm)	0.15	Planned down time	74%	Planned down time	76%
Max tool life (min)	250	Unplanned down time	10%	Unplanned down time	10%
Application		OEE	16%	OEE	14%
Width radial (mm)	30	Extra information		Impact of feed optimisation	
Depth axial (mm)	30	Engineering time (h)	1	G26	
Length to cut (mm)	1000	Part manipulation time (min)	20	100%	
Cutting conditions		Machine setup time (h/batch)	1	Impact of unreliable tooling	
Nbr of passes axial (x)	6	Insert index time per insert (min)	5	G29	
Nbr of passes radial (y)	2	First tool set up time (min)	20	100%	
Feed (f - mm/t)	0.1	Unplanned down time (%)	10		
Axial depth of cut (ap)	5	Batch size (# pieces)	10		
		Yield (%)	90		
		Radial depth of cut (ae)	15		
				Average chip thickness	0.06



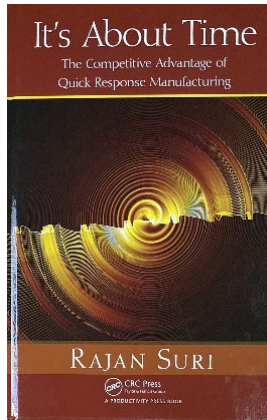
Beyond economic machining, the **NEXT STEP**

Small batch production - issues

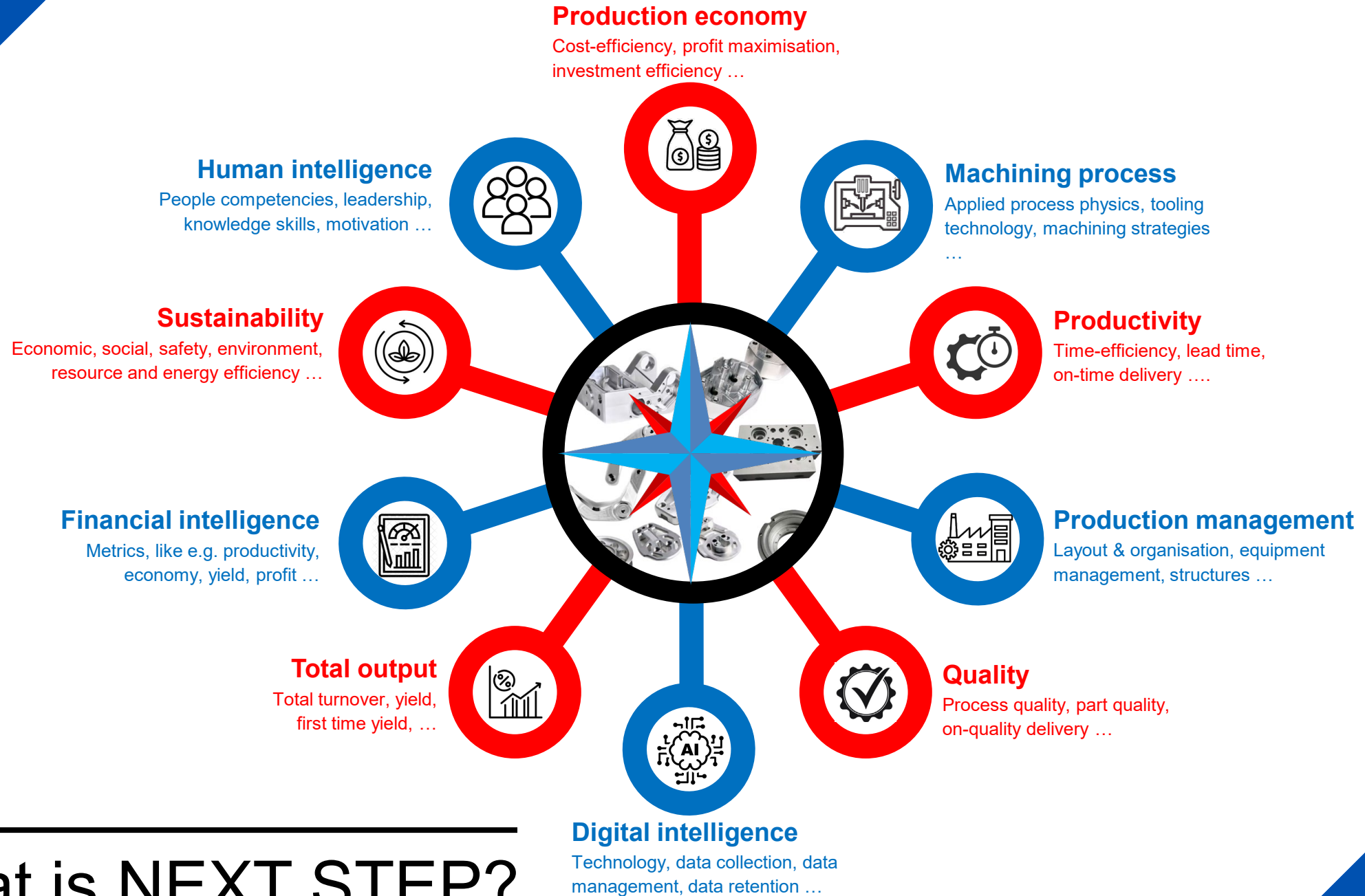
- How to improve the company's overall performance?
- Is production capacity used in a balanced manner?
- What could release extra capacity?
- Is correct technology being used?
- Do people have the right knowledge, skills and mindset?



A model for production excellence and sustainable machining in a small batch production environment in the contemporary manufacturing industry.



What is NEXT STEP?



What is NEXT STEP?

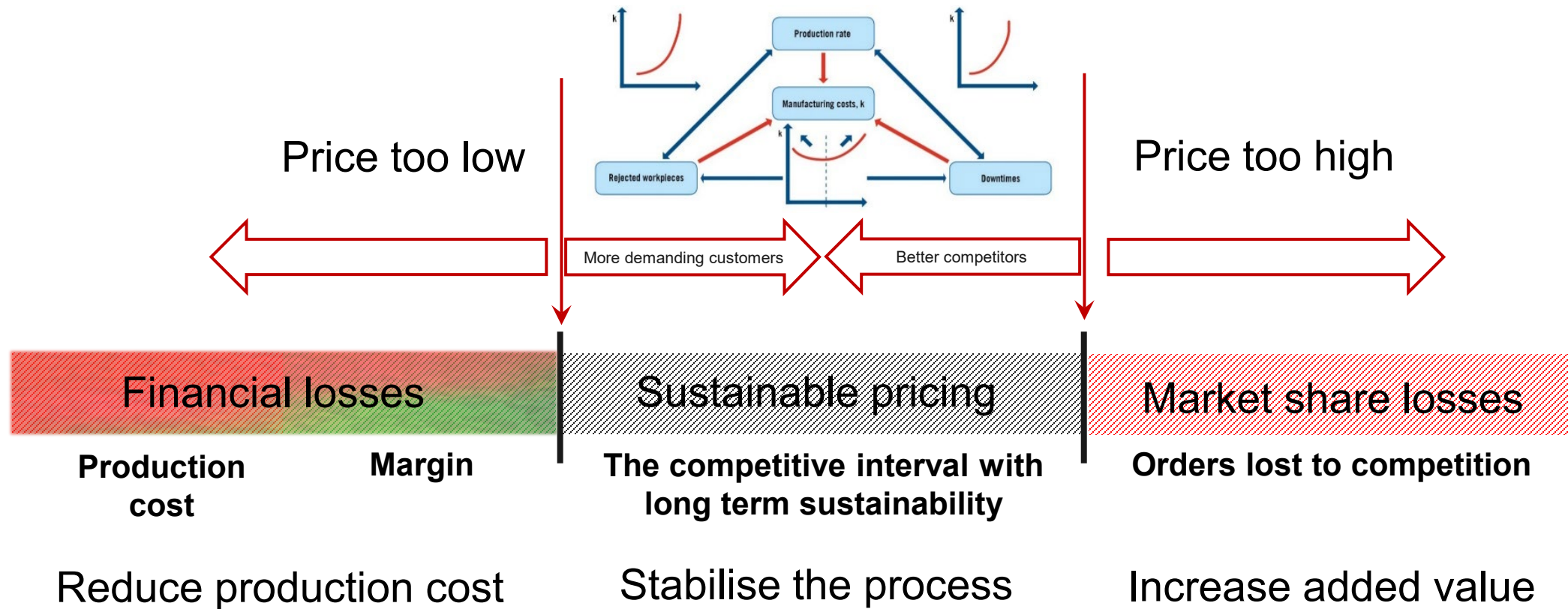
Why NEXT STEP?

- ❖ Less than 20% effective spindle hours (OEE) gives low ROI on machines and equipment.
- ❖ In the total manufacturing costs less than 10% is machining cost. This creates wrong pricing, lost orders, low profits.
- ❖ Chaotic planning and scheduling and numerous disturbances in the workflow leads to failure in reliable delivery service (OTD below 50%).
- ❖ High non-conformity of workpieces (OQD) gives pressure on total output and yield (first time yield below 40%).
- ❖ Finding, training and retaining well educated, skilled and motivated people is problematic and takes up more than 75% of the production manager's time.



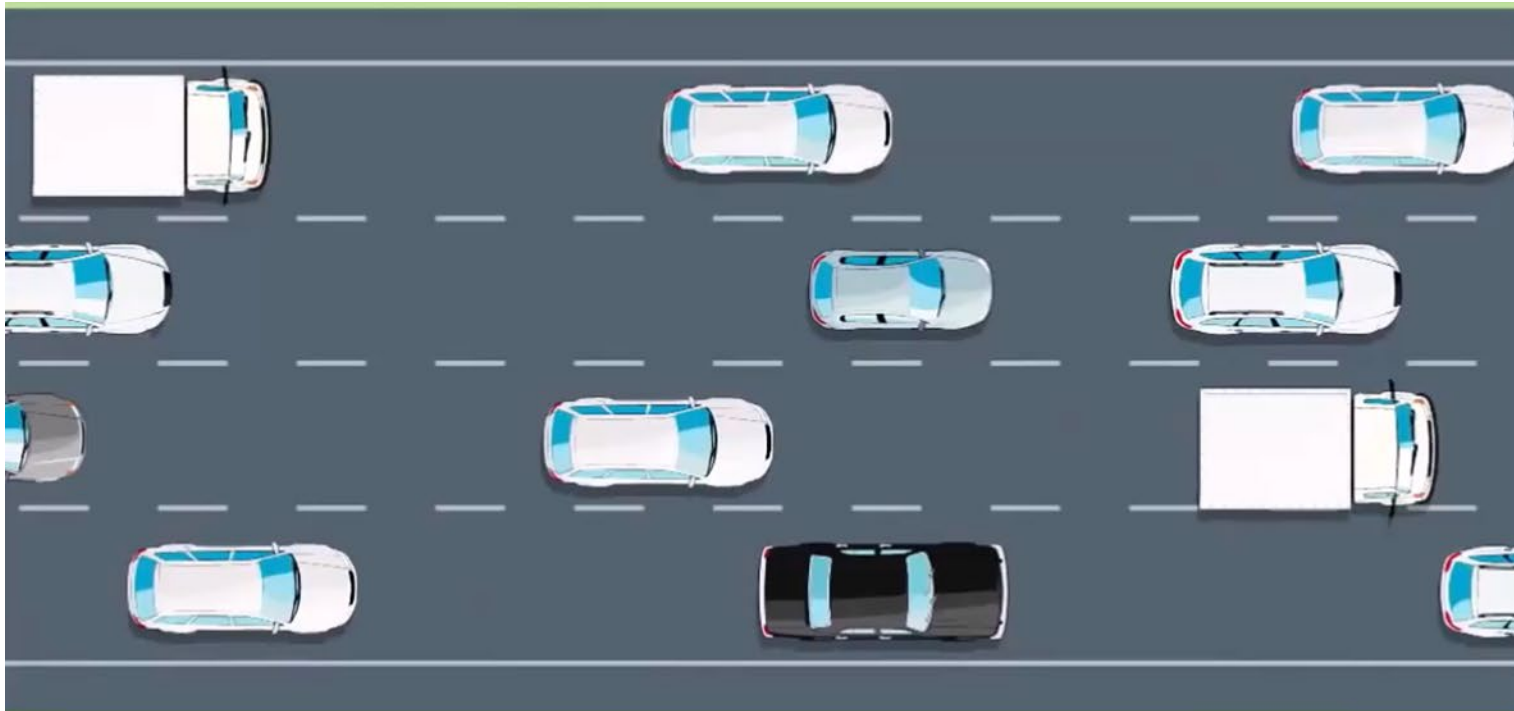
Why NEXT STEP?

The big challenge with small batch production is competitive and sustainable pricing.



Why NEXT STEP?

Pressure on delivery time and on-time-delivery.



Why NEXT STEP?

Pressure on part and process quality.





NEXT STEP concept and methodology

The scope of the process

Production excellence – the importance of sustainable and reliable machining processes and a continuous flow of work in progress from start to end.

Customers

Competitive advantages (FMTS), commercial strategy, customer relations ...

Machining

Available equipment, process control, quick reaction ...



Engineering

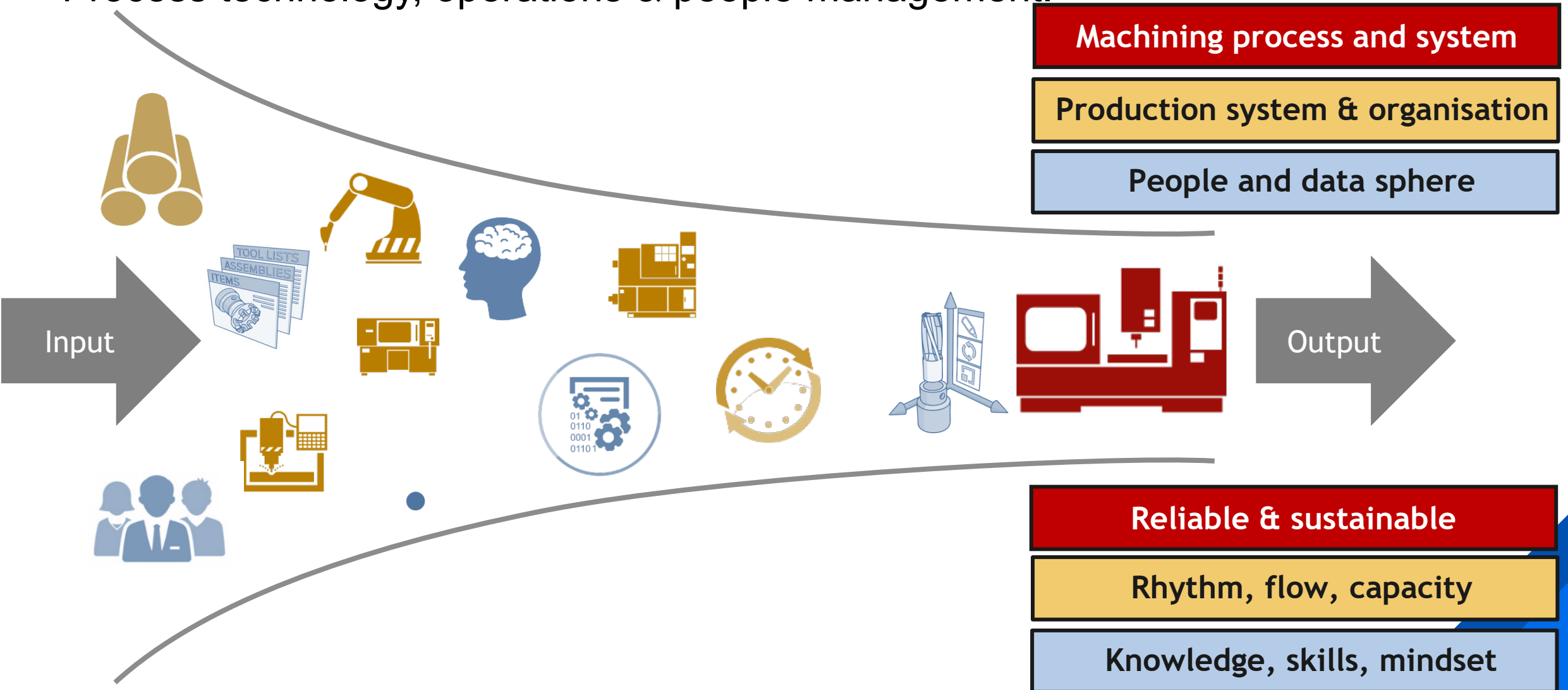
Available technology, technical strategy, knowledge ...

Workshop

Maintenance, inventory, practical scheduling, OEE, skills ...

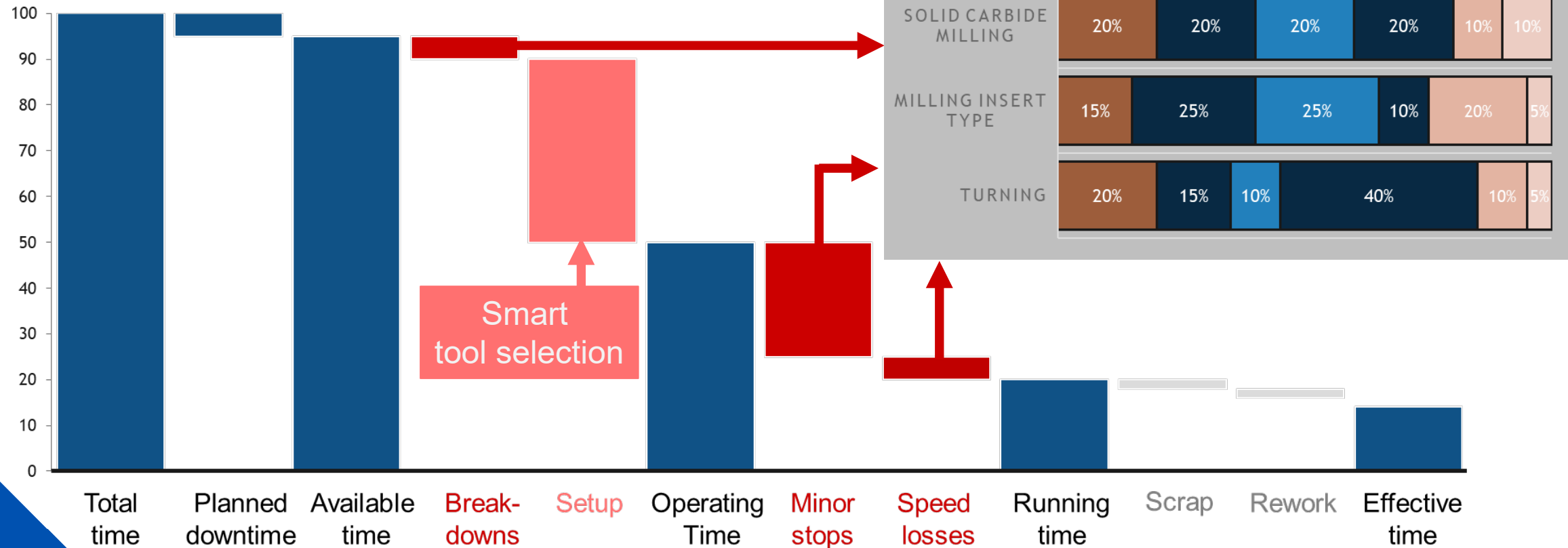
The layers in NEXT STEP

Process technology, operations & people management.



NEXT STEP defines a clear relation between machining technology and production organisation and management.

NEXT STEP uniqueness



OEE increase by 25+%

- Decrease in set-up time and manipulation time

Total production costs down 20+%

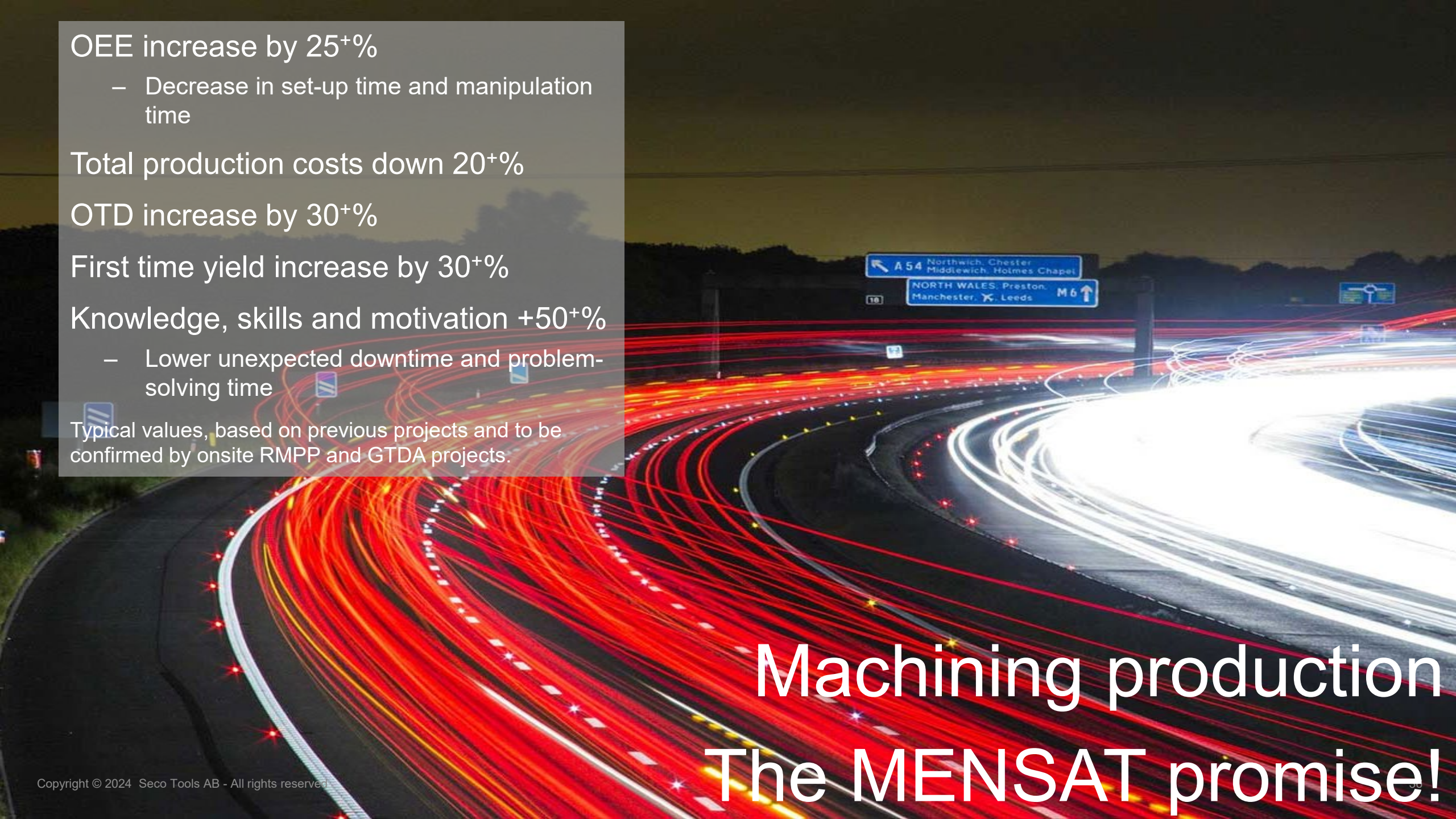
OTD increase by 30+%

First time yield increase by 30+%

Knowledge, skills and motivation +50+%

- Lower unexpected downtime and problem-solving time

Typical values, based on previous projects and to be confirmed by onsite RMPP and GTDA projects.



Machining production
The MENSAT promise!



The role of people



Unlike in mass production, where operators primarily oversee automated processes, small-batch machining requires operators to be deeply involved in process optimisation, troubleshooting, and decision-making.

They must be knowledgeable and experienced in machining technology, and process sustainability to ensure high-quality output.



- Develop **troubleshooting guidelines**: clear, structured procedures for diagnose, adjusting machining data and resolving machining issues.
- Provide **hands-on training**: simulated and real-world exercises in machining data selection and tool wear assessment.
- Encourage **process ownership**: operators should understand how their decisions impact quality, cost, and efficiency.
- **Continuous education and mentorship**: regular training sessions on emerging machining strategies, tooling advancements, and digital machining solutions.



Knowledge

Insight in and understanding of the theories and models



Skills

The capability to use and apply the knowledge



Equipment

Physical means to execute what needs to be done



Mindset

The urge to use the knowledge, skills and equipment

How to support operators for success



Where to start

The golden 4 for fast results

Focus points for a sustainable reduction of the production cost, a higher productivity, better part quality, and an improved customer satisfaction.

Technology

Challenge always the technology of processes. Constantly improve machining processes to stay on the edge (machining economics).

Machine utilisation

Increase machine utilisation. Optimised spindle times reduce costs and lead times (setup times are the biggest concern).

Unexpected downtimes

Reduce unexpected downtimes. Awareness of real downtimes and what causes them, ensures true productivity and cost efficiency.

People

Build (finding and retaining) a flexible and multi-disciplined team of experts (operators, engineers, managers).



A key element for a sustainable future for the machining industries is finding, training and retaining good operators, engineers and managers.

A MENSAT Masterclass is a management development programme for executives and professionals managing machining production plants.

Available literature




Pocket guide
Optimised machining data
for small batch production




Pocket guide
Tool selection from strategy to
shopfloor.
A pocket guide to smarter machining decisions.




Pocket guide
The boring advantage.
Precision, repeatability, and
control where it counts most.




Pocket guide
Chip control in machining and
its impact on profitability and
sustainability




Pocket guide
Balancing cost & time efficiency,
with sustainability for profitable
small batch output




Pocket guide
Machining strategies for small
batches of high quality parts




Thank you!