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Evaluating the trade-off : mid-scale vs large-scale LNG trains in the modern energy landscape

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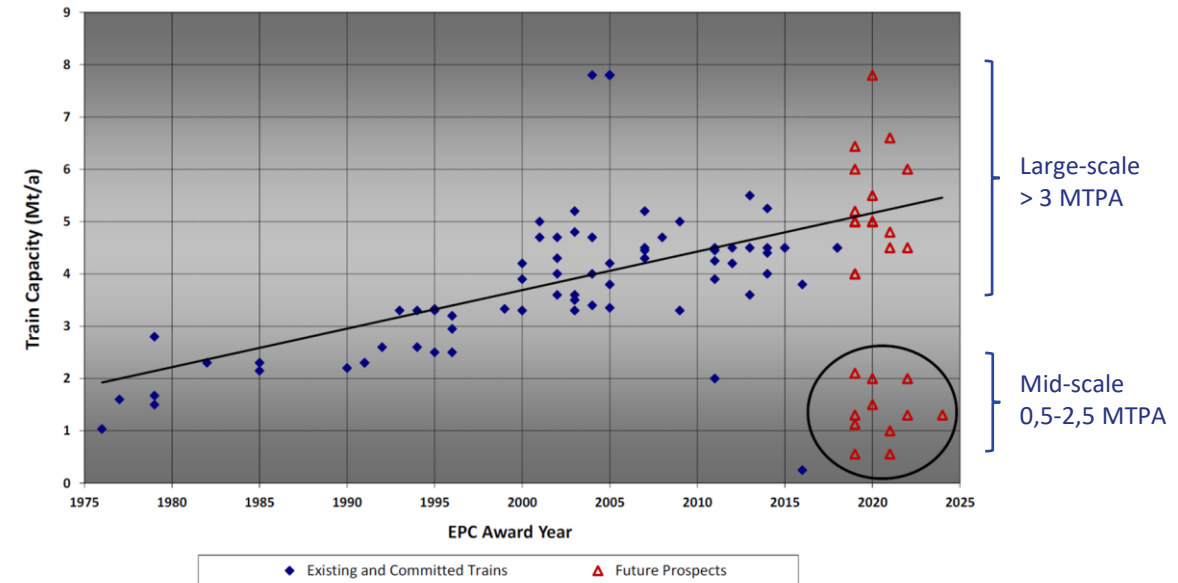
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VP Early Engagement Gas

Technip Energies

Train Sizing for LNG facility

- Context : Trends / Drivers for mid-scale
- Question :
3 x 1,5 MTPA or 4,5 MTPA ?
Large-scale ↔ Economies of Scale
Mid-scale ↔ Risk / NPV / Certainty
- A Complex / Multilayered problem :
 - Technology selection
 - Economics / Context / Market
 - Construction Strategy / **Modularization** / O&M
- Difficulty:
 - Grasp tendencies through complex system modelling
 - identify relevant constraints & parameters
- Present analysis focuses on:
 - Modularization (Size)
 - Schedule



From Caswell, C. & Attaway, D. LNG2019, Shanghai (2019).

- Train scale and module scale : how modules size impact the execution?
- How modularization specificities help to get insights into train sizing?



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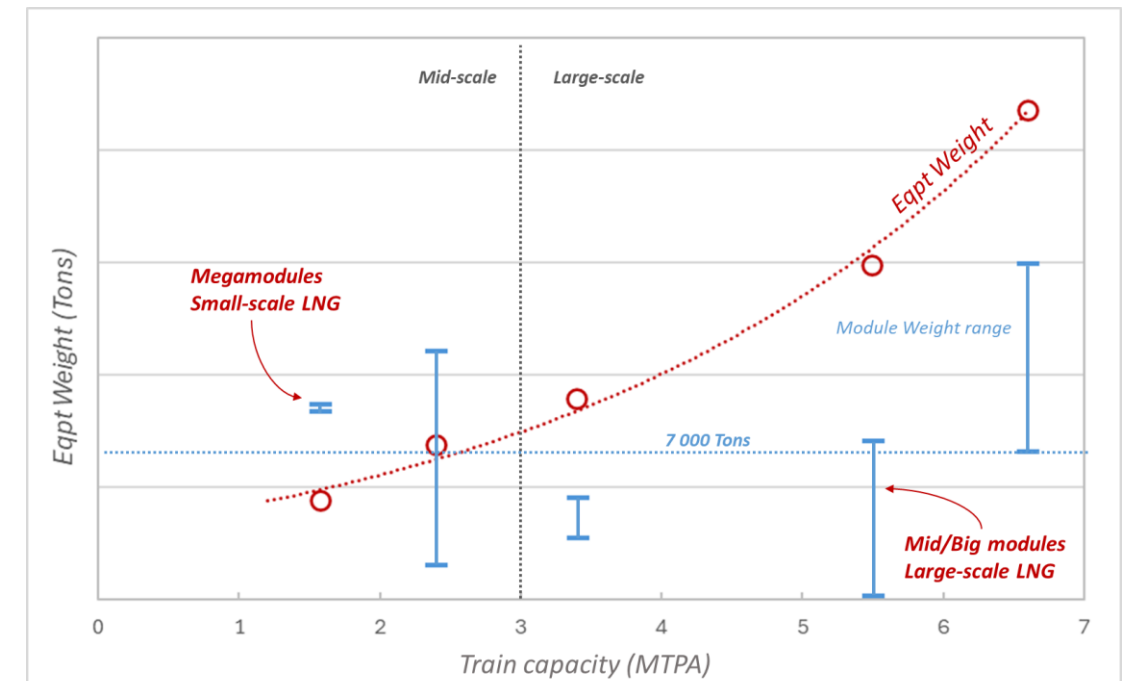
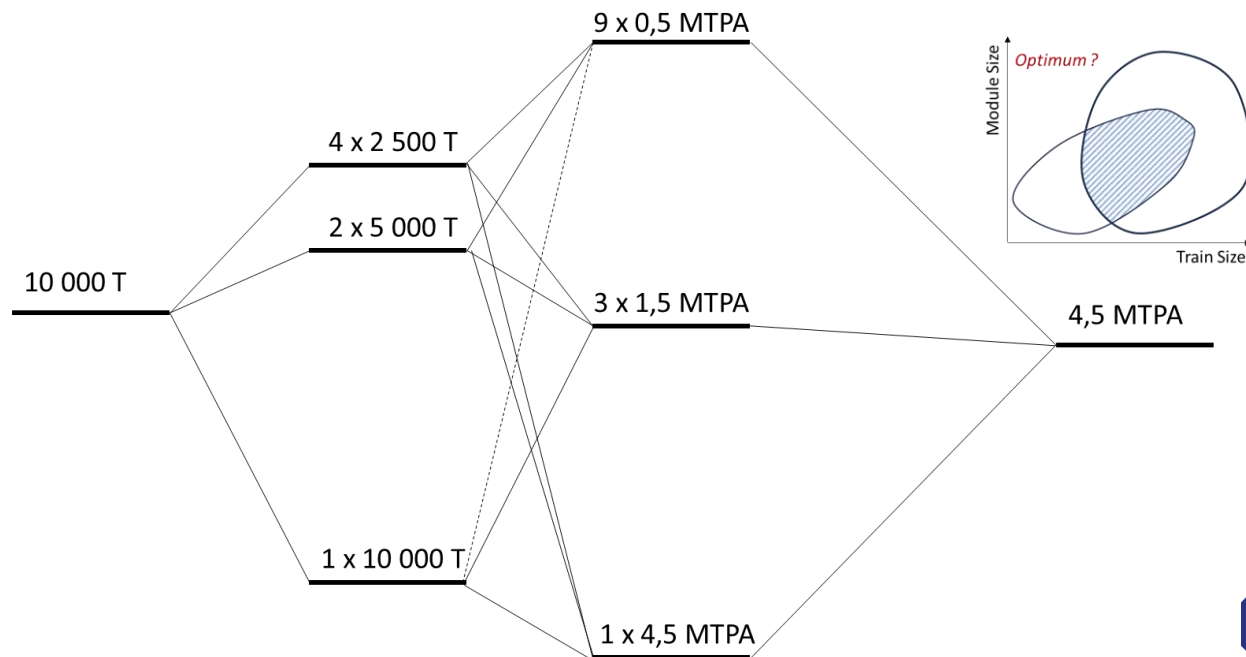


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Module size & Train size

- Modules dimensions are a consequence of logistics constraints
- Train Size and Module Size are not correlated
- New side question:

How module size impact Execution ?



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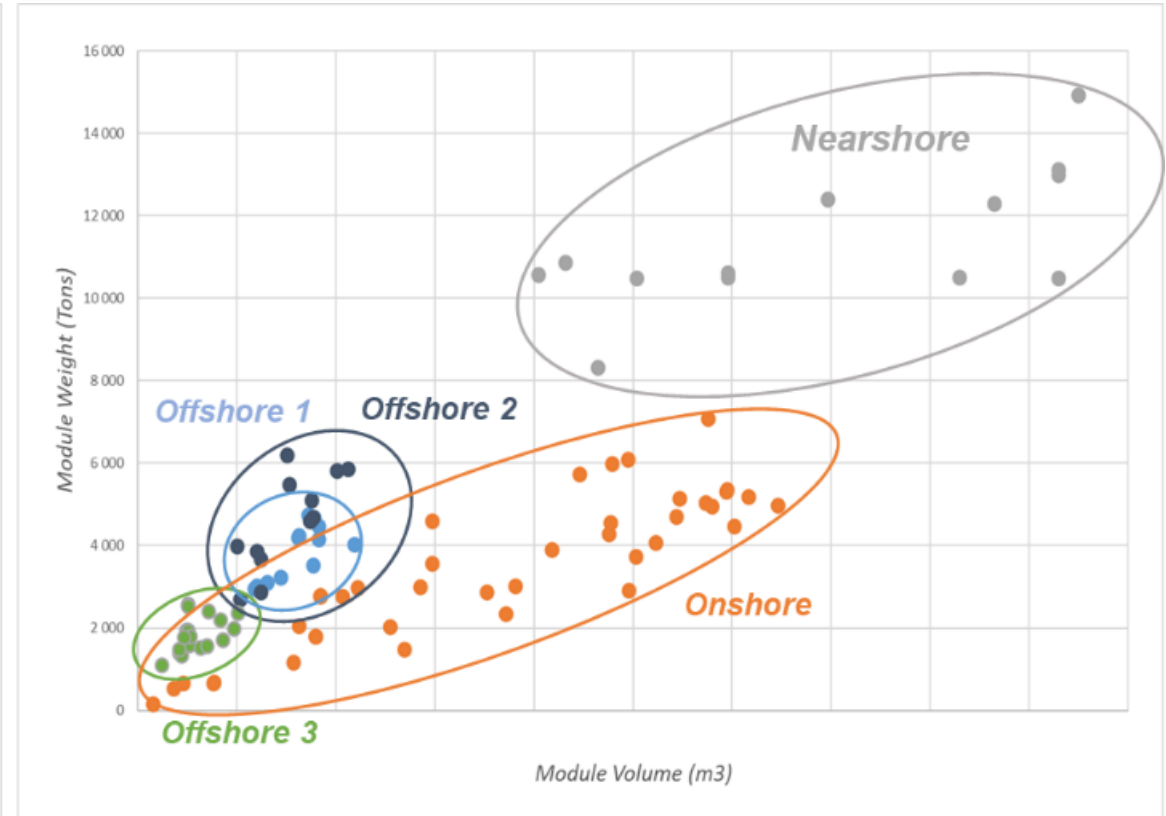
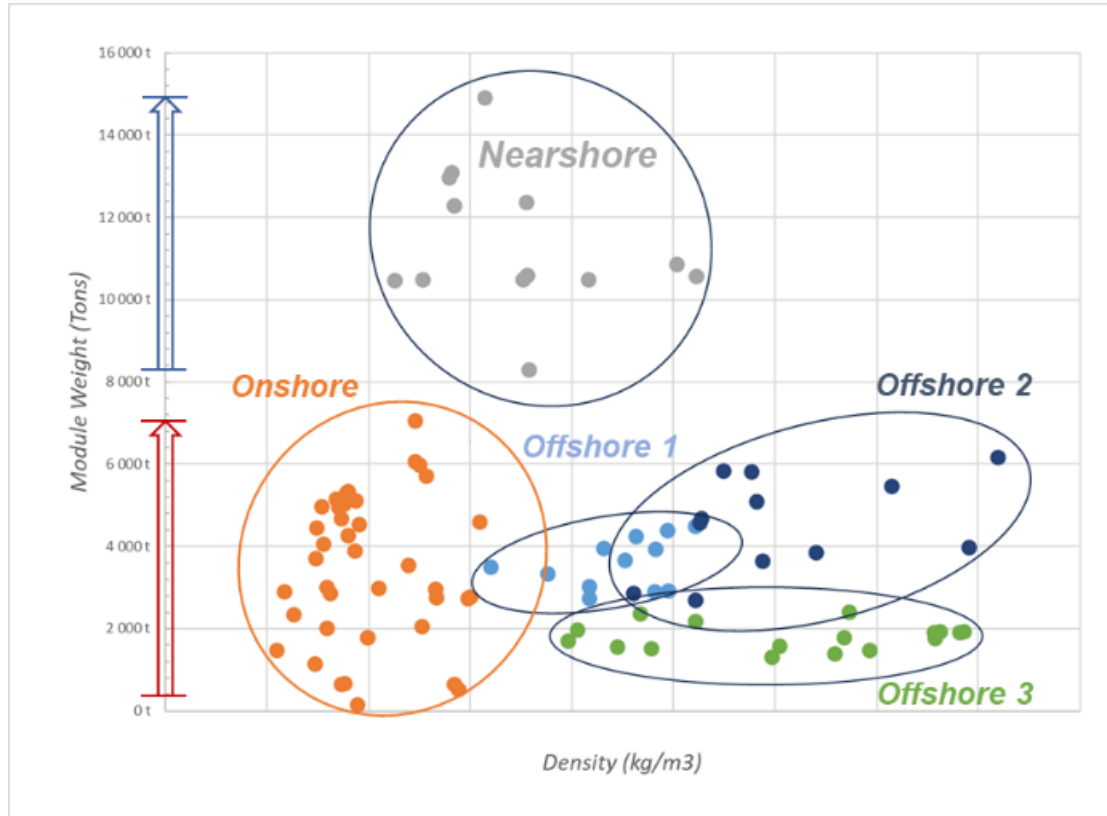


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Module Size & Weight : an overview



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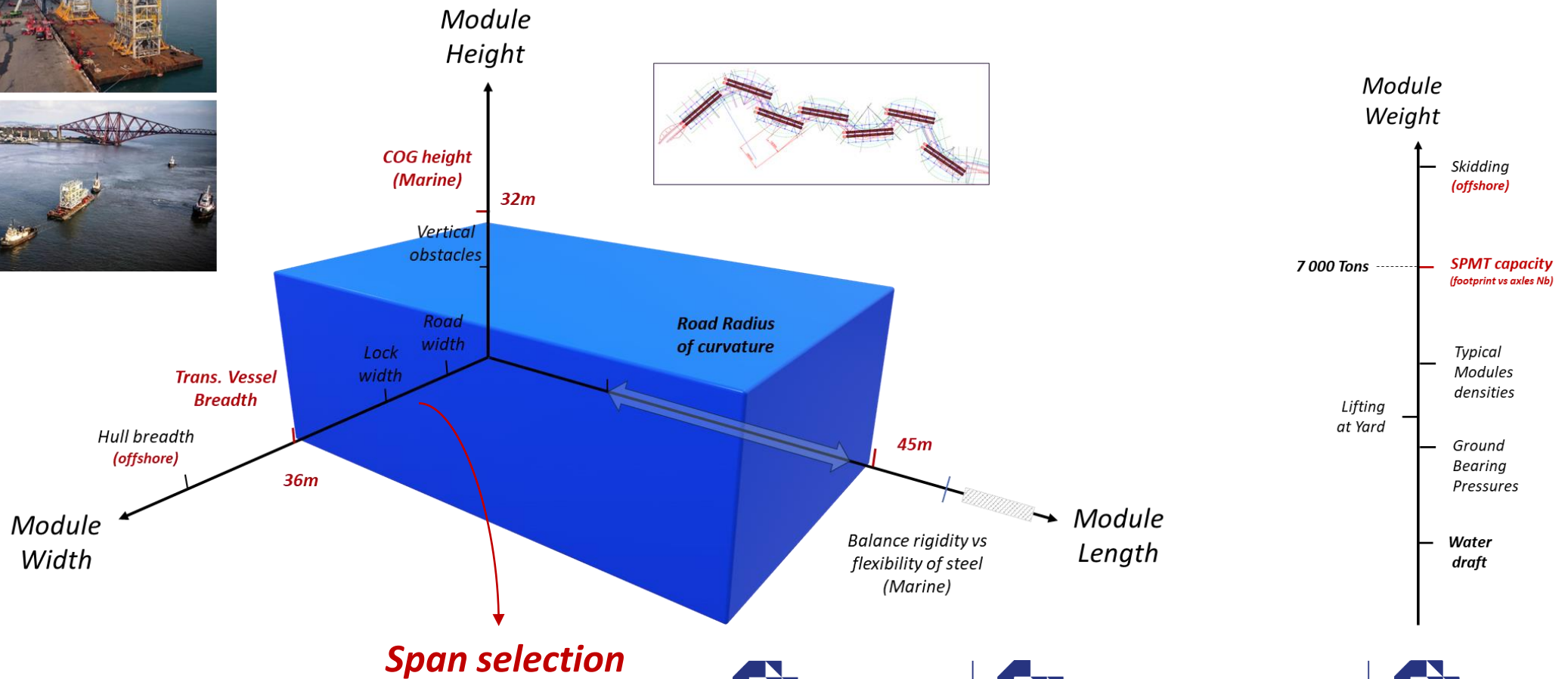


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Module Size derives from logistics constraints



Size ↔ *Weight*



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Modularization : from a continuum of size/weight to *only a few possibilities*



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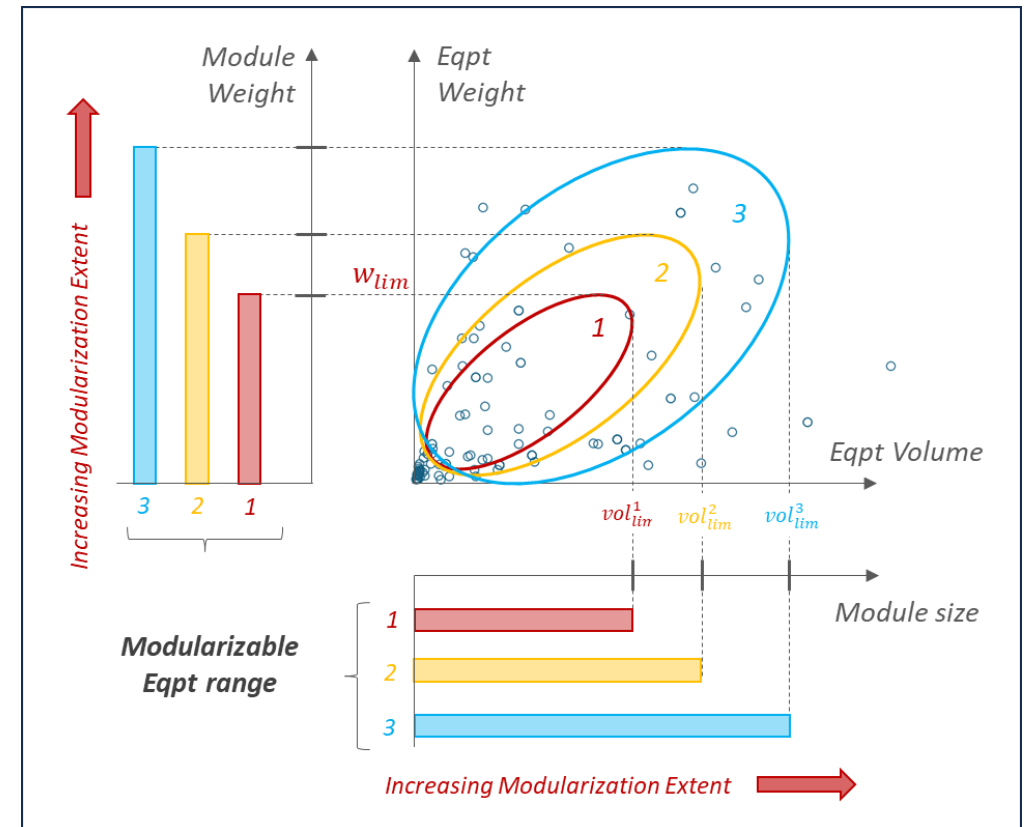
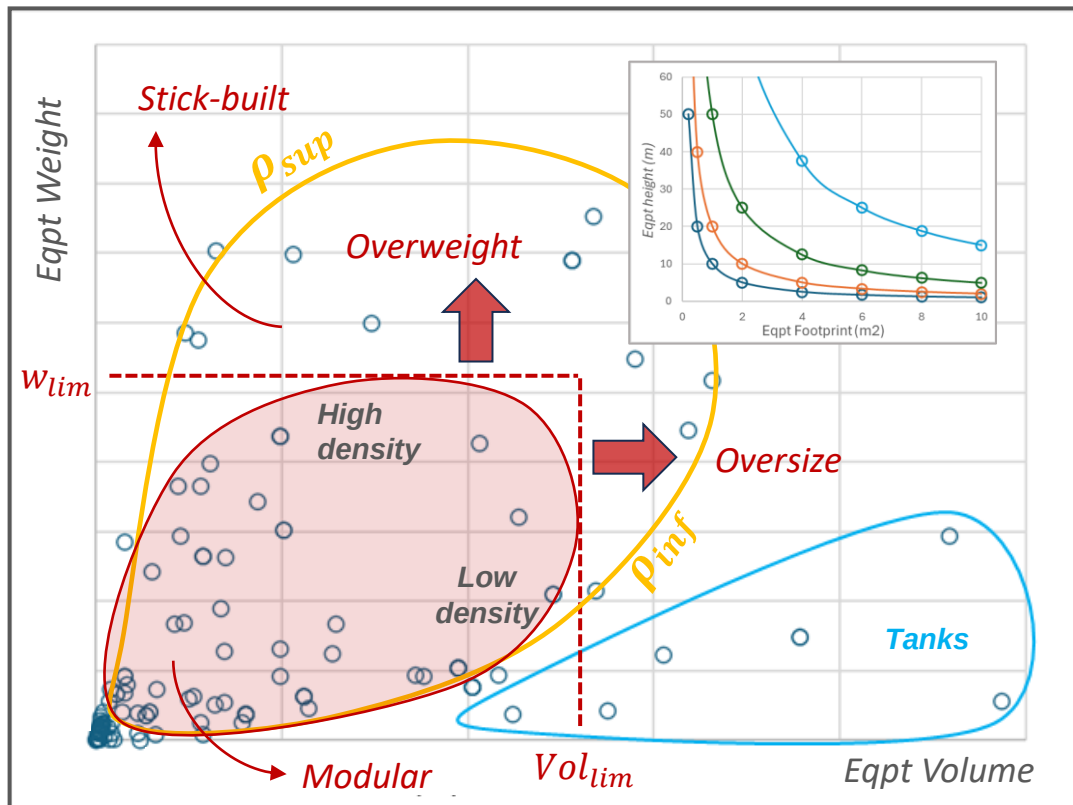
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Equipment, Modules & Modularization Extent

- Criteria to modularize equipment : Eqt vs Module size & weight
- How module size impact the modularization extent



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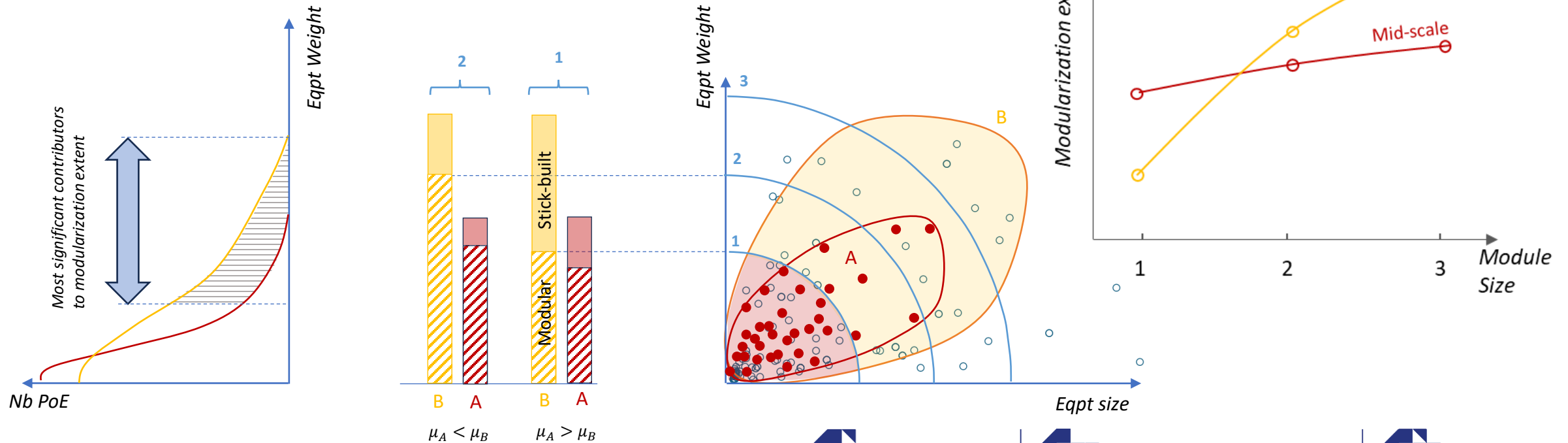


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A first comparison : Mid/large scale Trains & Modularization Extent

- ***Eqpt signature*** (Weight & size) for Mid & Large-scale Trains and ***module envelope***
- Modularization extent (one way to define) :
$$\mu = \frac{1}{W} \sum_i w_i x_i$$
- One selection criteria : Logistics & Eqpt signature:

Maximizing modularization may drive train size



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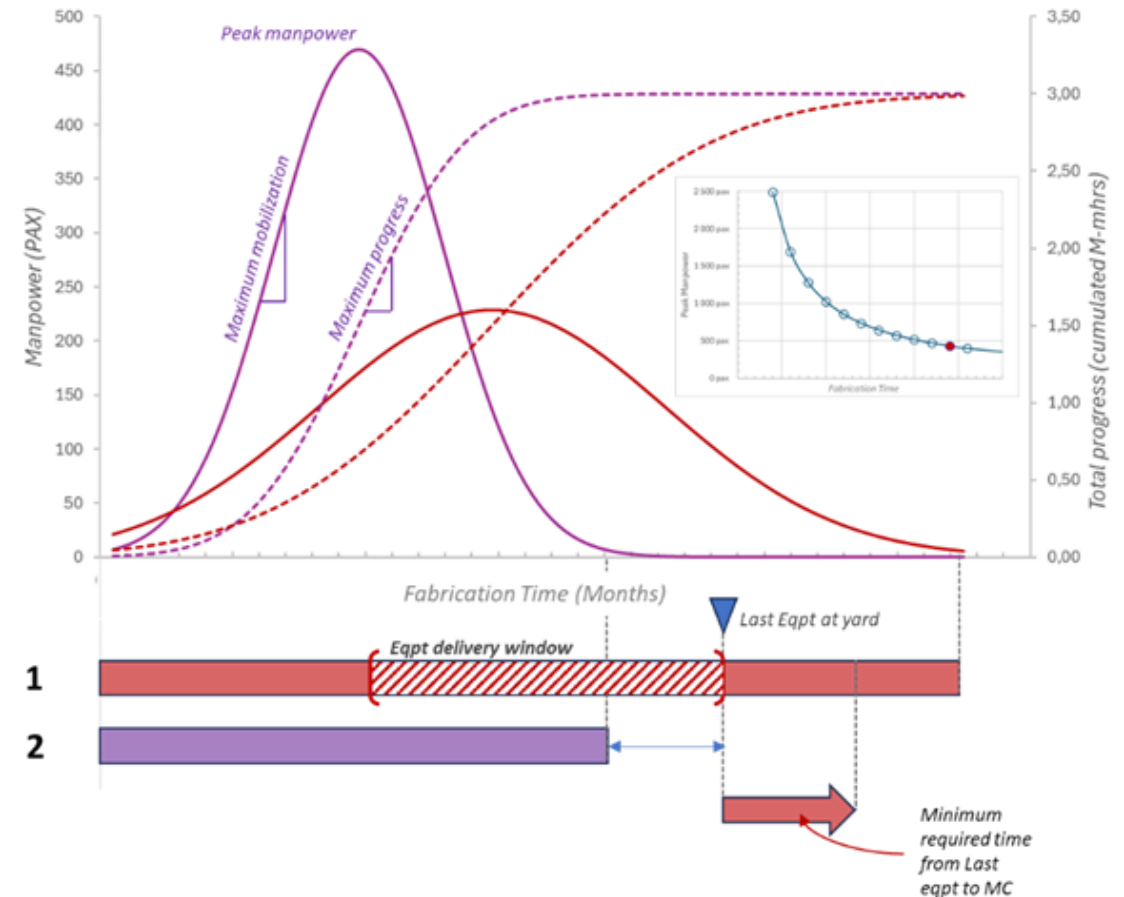


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Schedule Considerations : Single Module Fabrication

- Understand *what drives module fabrication* to get insight into train size selection.
From single module level to overall schedule
- Question : To which extent can module fabrication time be reduced?
- Key factors:
 - Sequencing → **upper limit for progress**
→ max manpower (congestion)
 - Equipment Delivery → **uncompressible window**
→ minimum time to MC
 - Yard workload/capacity → **manpower mobilization**

What is the limiting factor ?



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Schedule Considerations : Single Module Fabrication

- Maximum Monthly progress β : 5%-6%

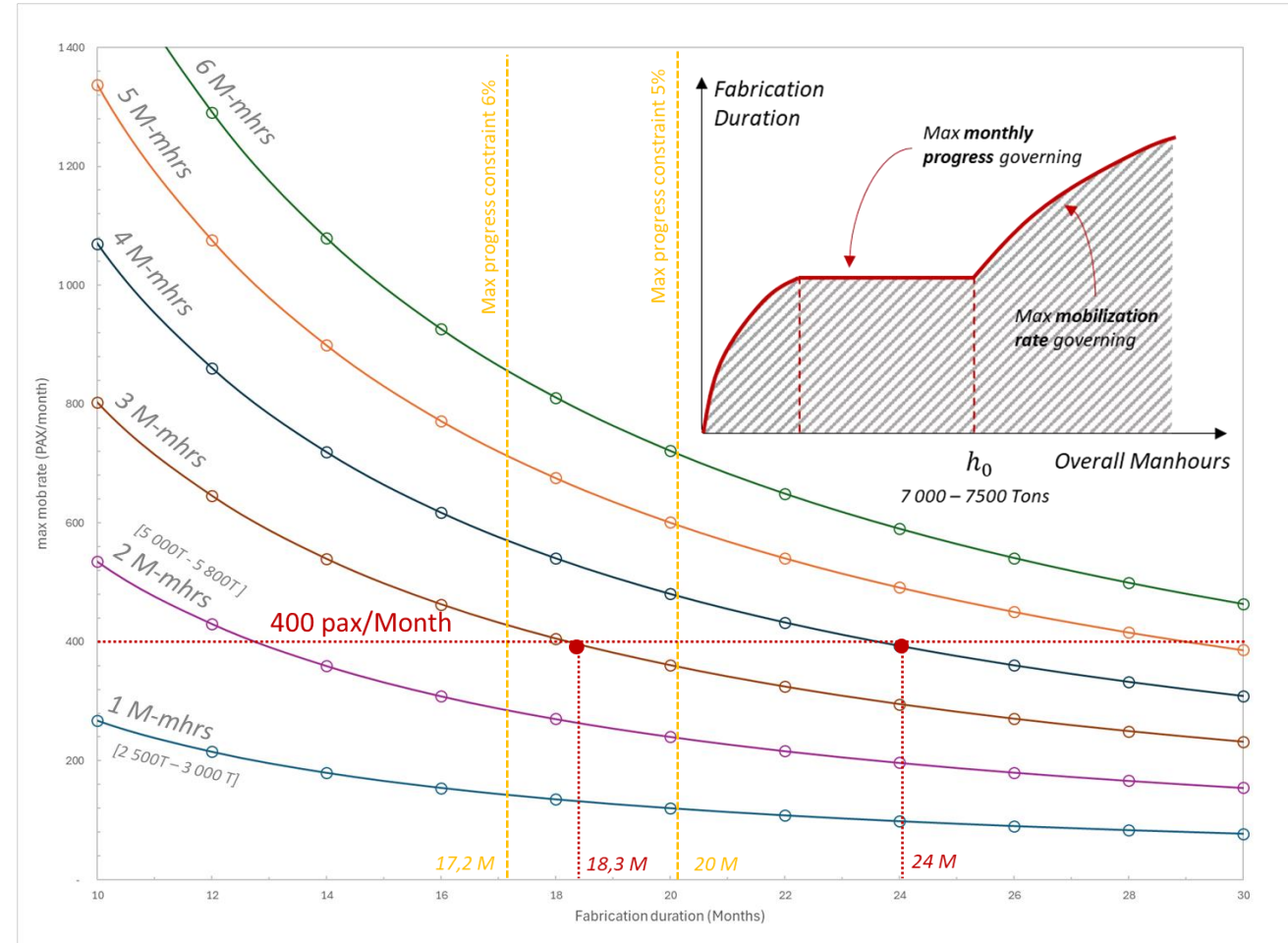
$$d_{min} \propto \frac{2}{\alpha \beta \sqrt{2\pi}}$$

Max monthly progress
Dispersion coefficient

$$d_{min} \in [17.2 \text{ Months} ; 20.5 \text{ Months}]$$

- Max manpower mobilization : 300-400 PAX/month

$$d_{min} \propto h_0^{\frac{1}{2}}$$



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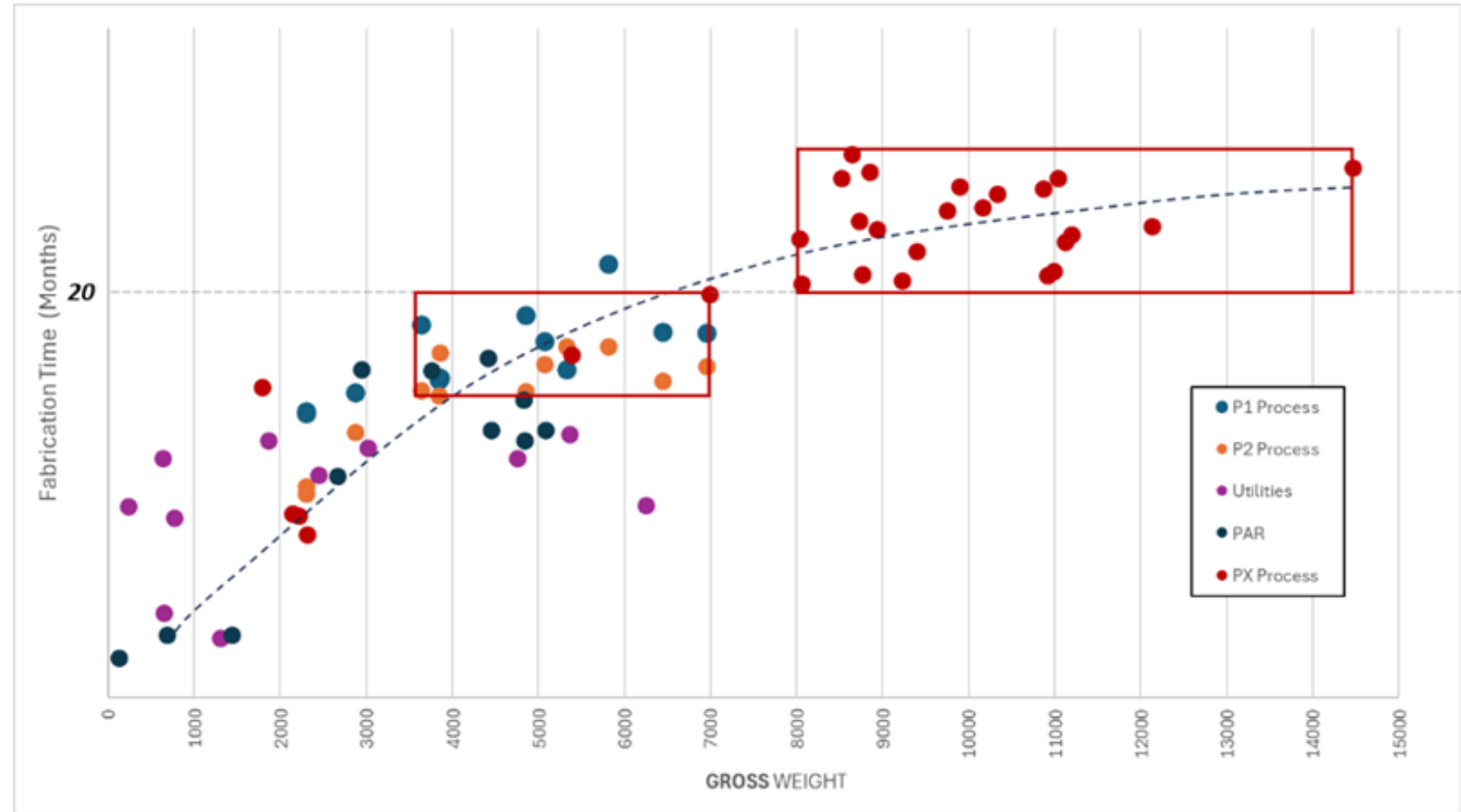


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Schedule Considerations : Single Module Fabrication

Link to reality:

- Non-linear scaling
- Small/Mid/Large scale



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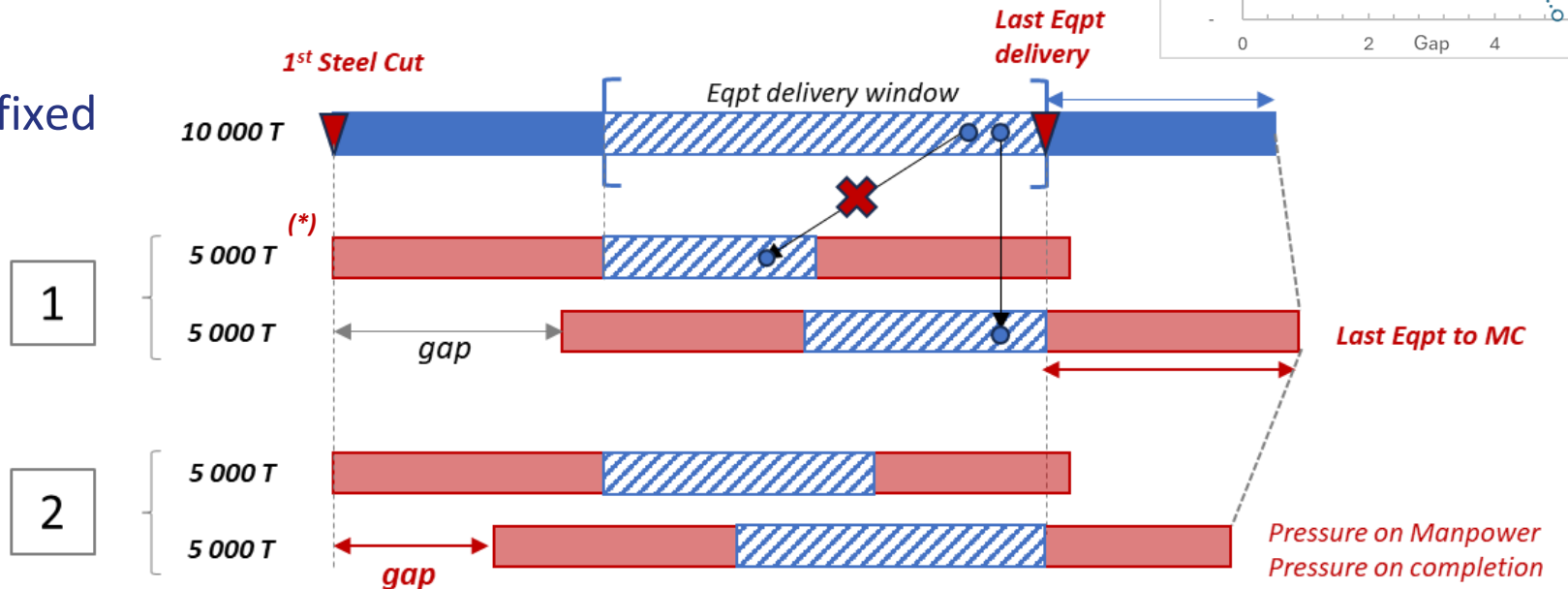
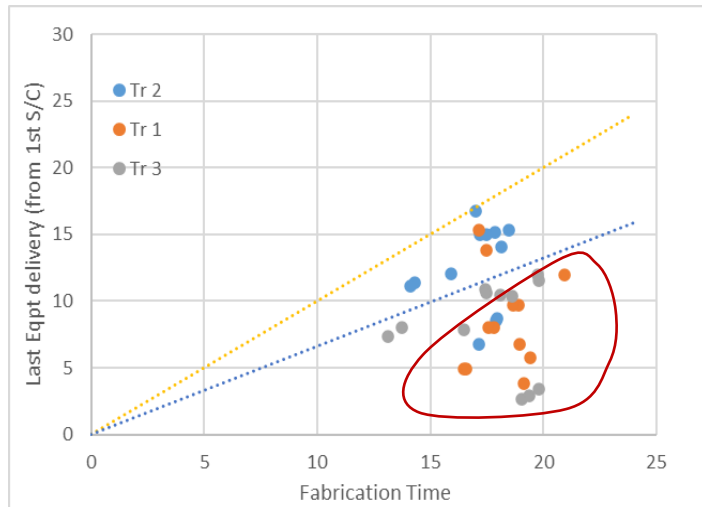


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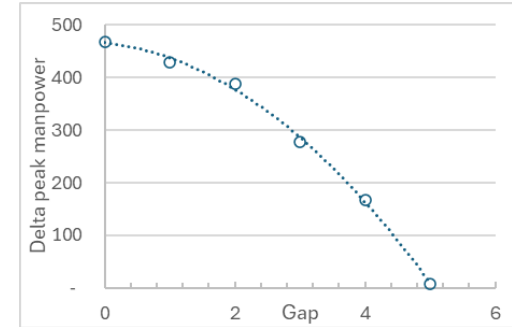
Going further : multiple modules

Case Study : 10 000 T vs 2 x 5 000 T^(*)

- Uncompressible milestones:
 - 1st Steel Cut
 - Equipment Delivery
- Last Eqpt delivery drives → gap fixed
- Gap drives → Last Eqpt fixed



(*) : it should rather be 5 600 Tons (Steel decreases as module size increases : economy of scale)



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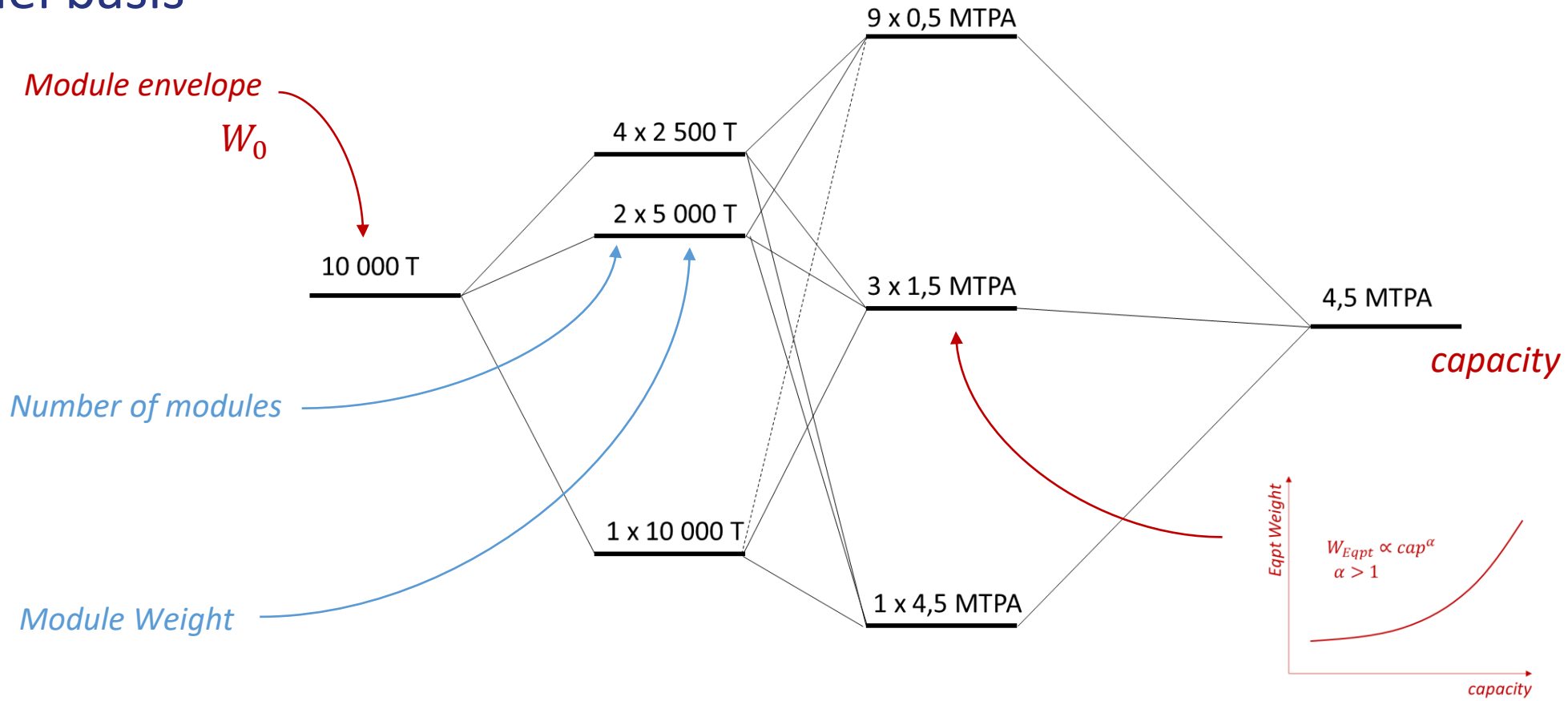
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Going further : Overall Schedule

Model basis



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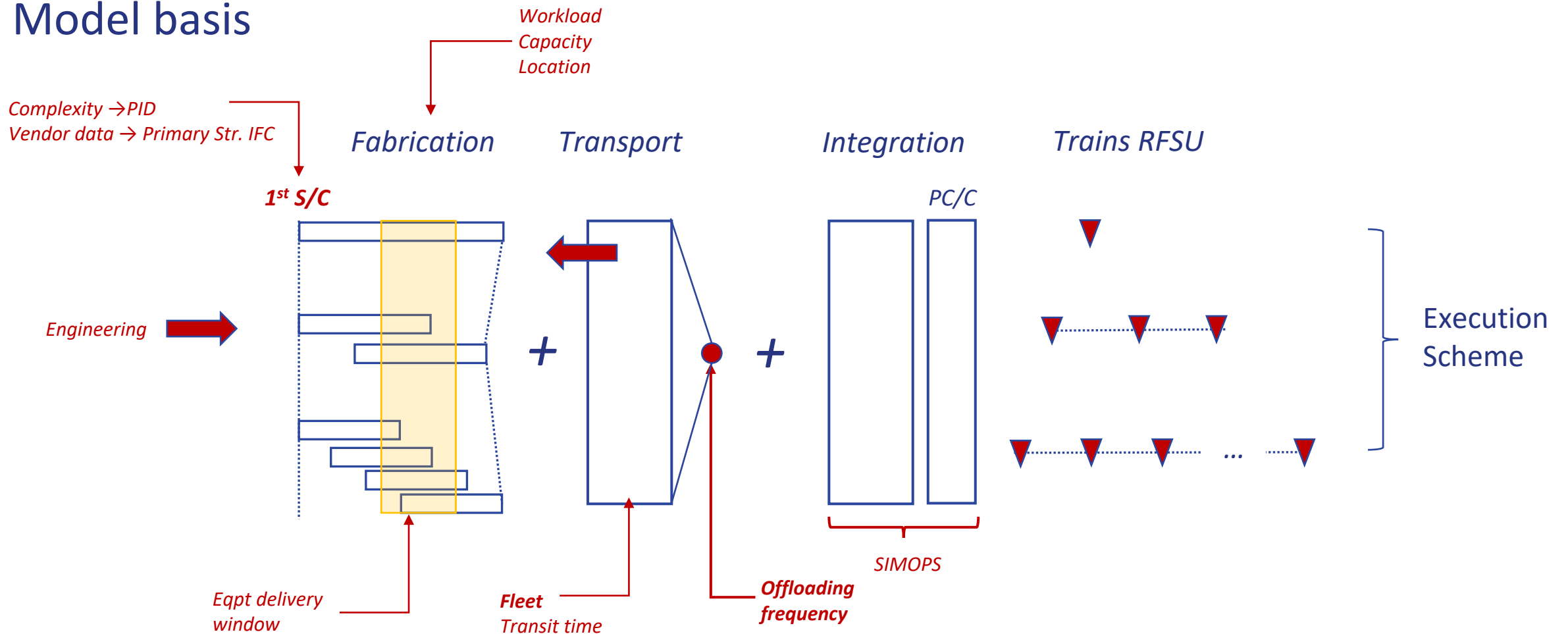
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Going further : Overall Schedule

Model basis



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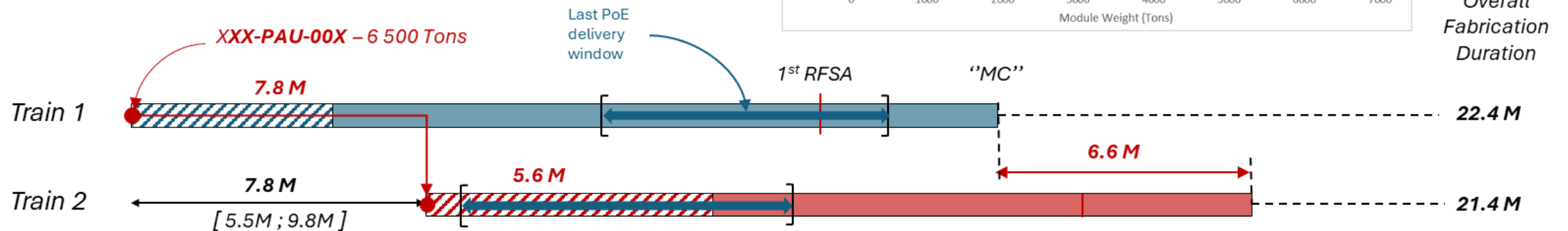
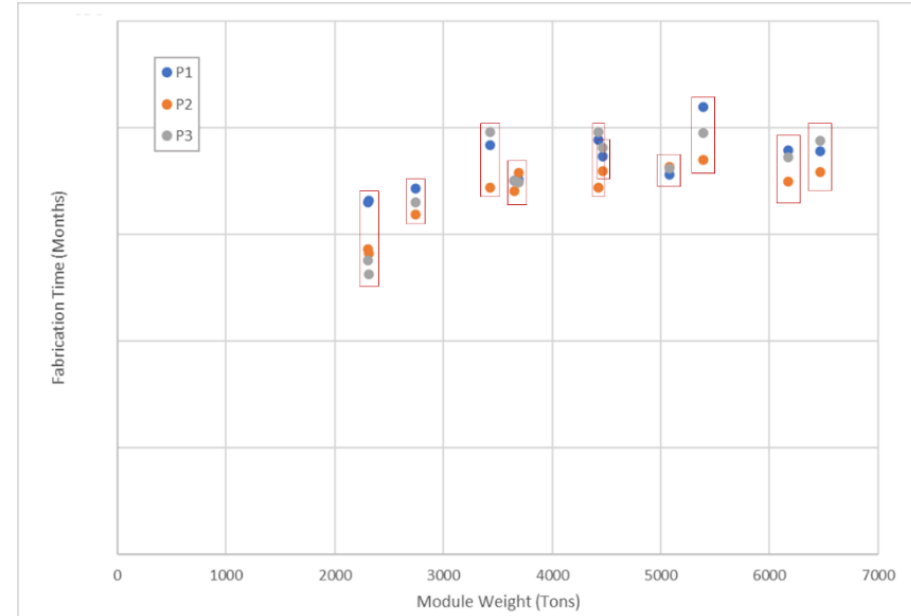
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Replicability & Staggering

- Parallel or Staggered Construction?
- Learning Effect / Benefit of replicability



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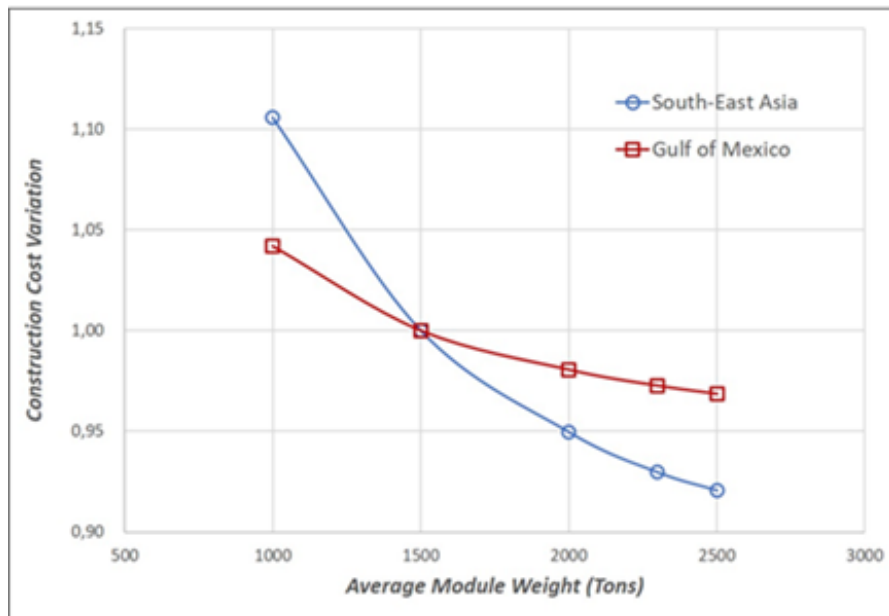


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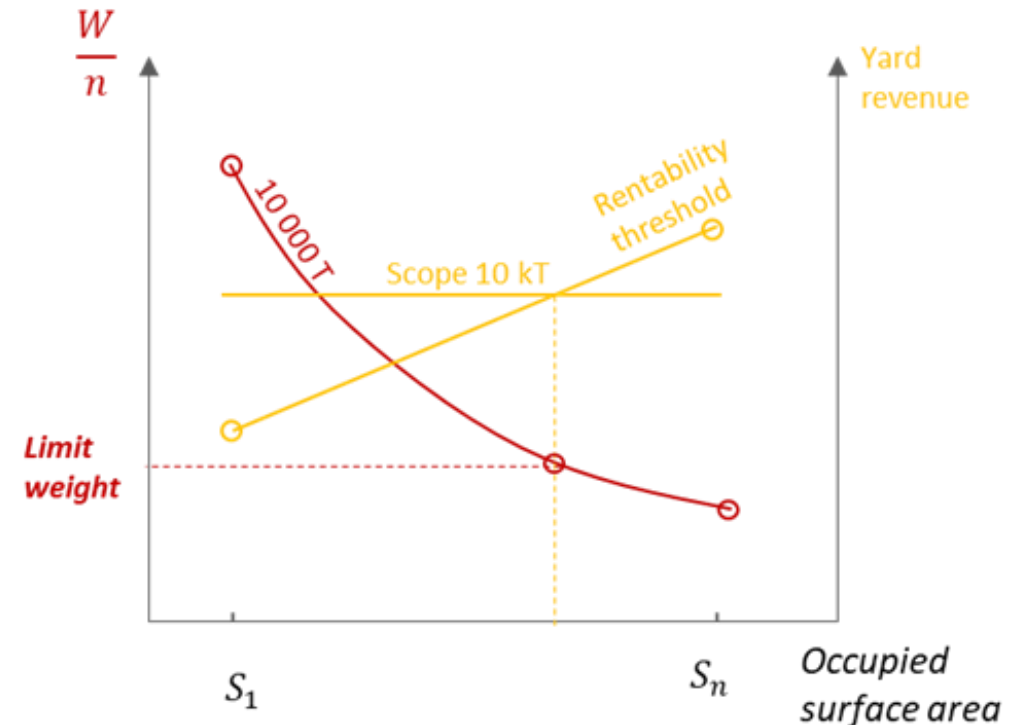
Module scale and Cost considerations

Illustrations of size effect

Crossover Small / Big Modules



When space drive fabrication cost



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