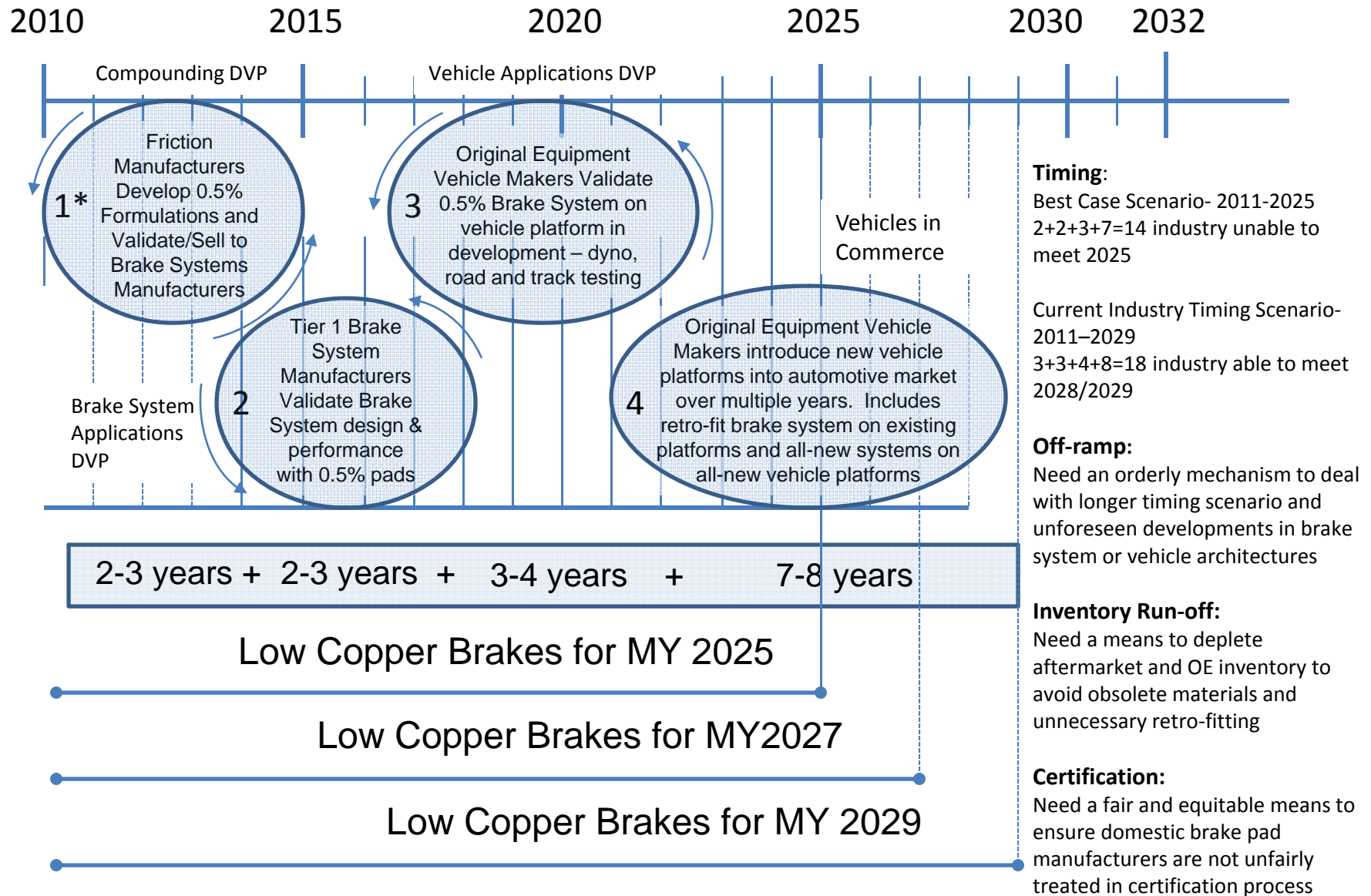


# The Standard Development Process Timeline and Brake Copper Reduction – Iterative, Overlapping Cycles of Development

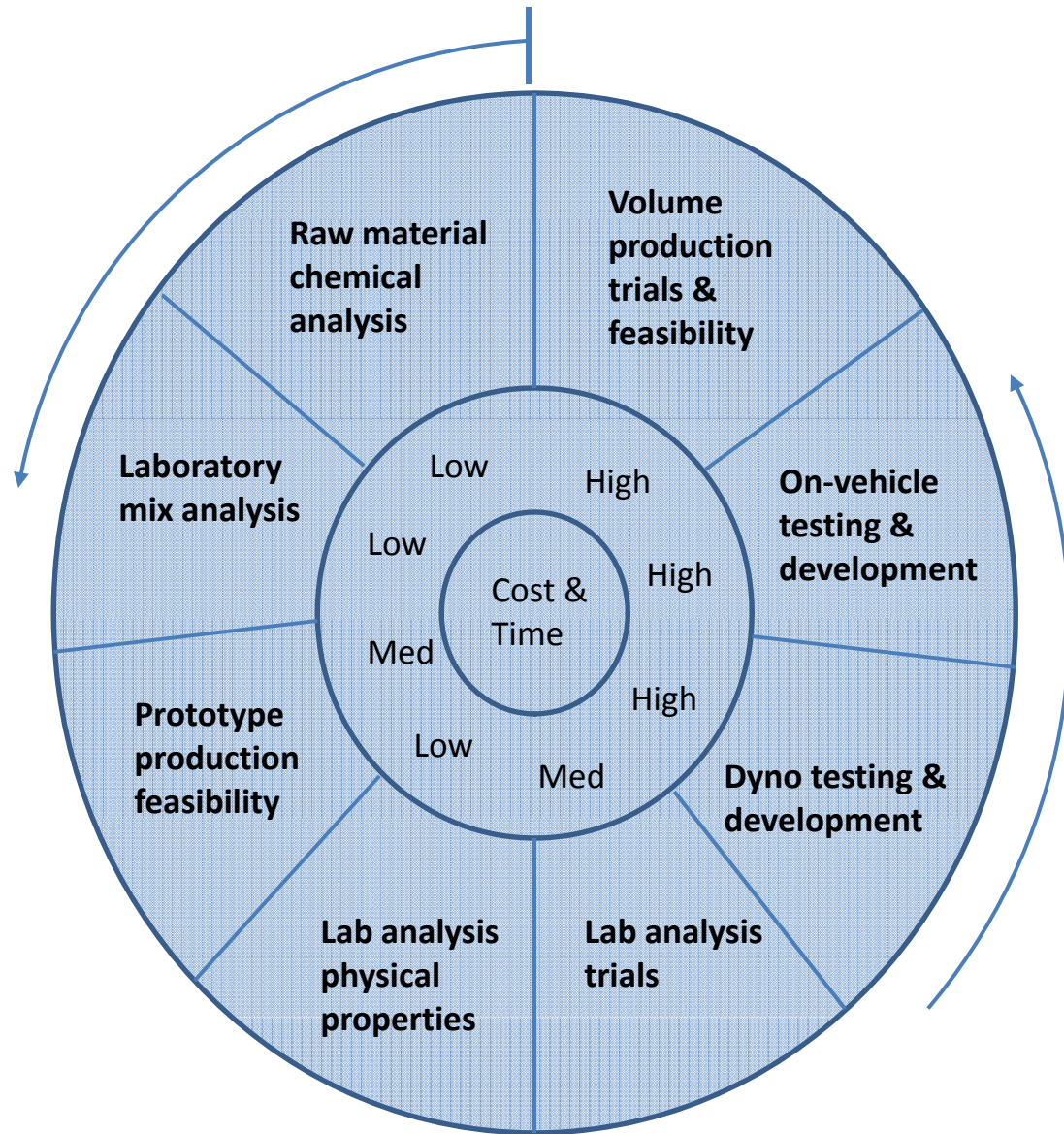


\*See next page for detailed development process steps for phases 1-3

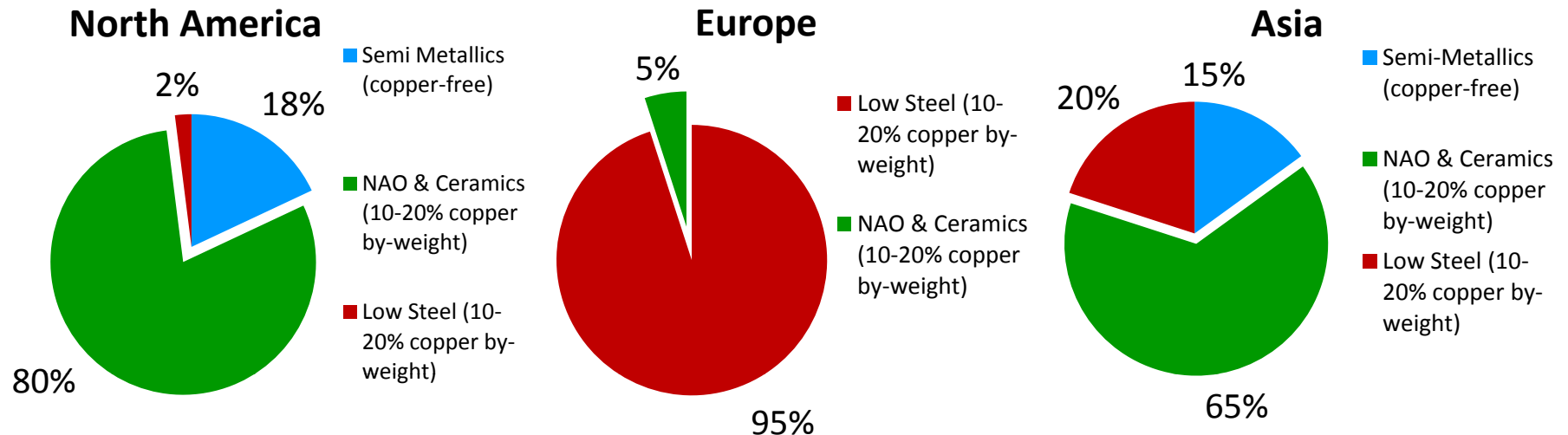
# The Standard Development Process Timeline and Brake Copper Reduction

## Description of Activity in Development Phases 1-3

- New friction formulations often require 6 or more development cycles to completion
- Each development cycle is 6-8 months
- Estimated cost of each cycle is \$75k
- A limited number of compounds ever complete full cycle of development
- Development includes materials formulation, volume manufacturing feasibility, durability and performance testing on dynos and on vehicles



## Brake Friction Formulation Alternatives & Market Penetration - 2009



### The Task is Enormous

- Majority of vehicles in North America have been engineered and developed for copper-type pad
- Semi-metallics do not meet performance requirements for many platforms
- 150 light-duty vehicle nameplates in California
- 8 major compounding suppliers each have 25-35 registered brake friction formulations, the majority of which will have to be reformulated to remove copper
- Over 250 vehicle platforms in market, each with 2-3 brake system variants
- Brake disc friction is not a one-size-fits-all technology. Disc pads, rotors and calipers are designed in iterations among friction pad supplier, brake system Tier1 and vehicle maker
- Each step of vehicle development can have consequences for brake system design and manufacture
- Even after ultra-low copper formulations are developed, the entire vehicle fleet and aftermarket supply chain transformation is a multi-year task