A Knowledge Domain Structure to Enable System Wide Reasoning and Decision Making

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CONTENT

- Context
- Language elements and information structure
- Knowledge domain pattern
- Knowledge domain structure
- Conclusions

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CONTEXT: SUPPORT REQUIRED TO HANDLE COMPLEXITY GROWTH

To architect and design a system, decisions on trade-offs have to be made

- Architect satisfies stakeholder needs by technical solutions

Trend is that the system complexity increases[1]

- Number of functions, components, and interfaces increases

Reasoning about decision impact becomes increasingly hard

- Tracing the decision impact throughout the system is crucial

To handle complexity growth, architects require support for:

- Understanding of and reasoning about decision impact
- Tracing decision impact throughout the system

[1] INCOSE, "A world in motion - Systems engineering vision 2025," International Council on Systems Engineering, 2014.

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CONTEXT: DECOMPOSE SYSTEMS IN KNOWLEDGE DOMAINS

- Knowledge domain (KD): specific area of knowledge and information by a team

- Running example: electric bicycle case
  - Trade-off on cost and usage

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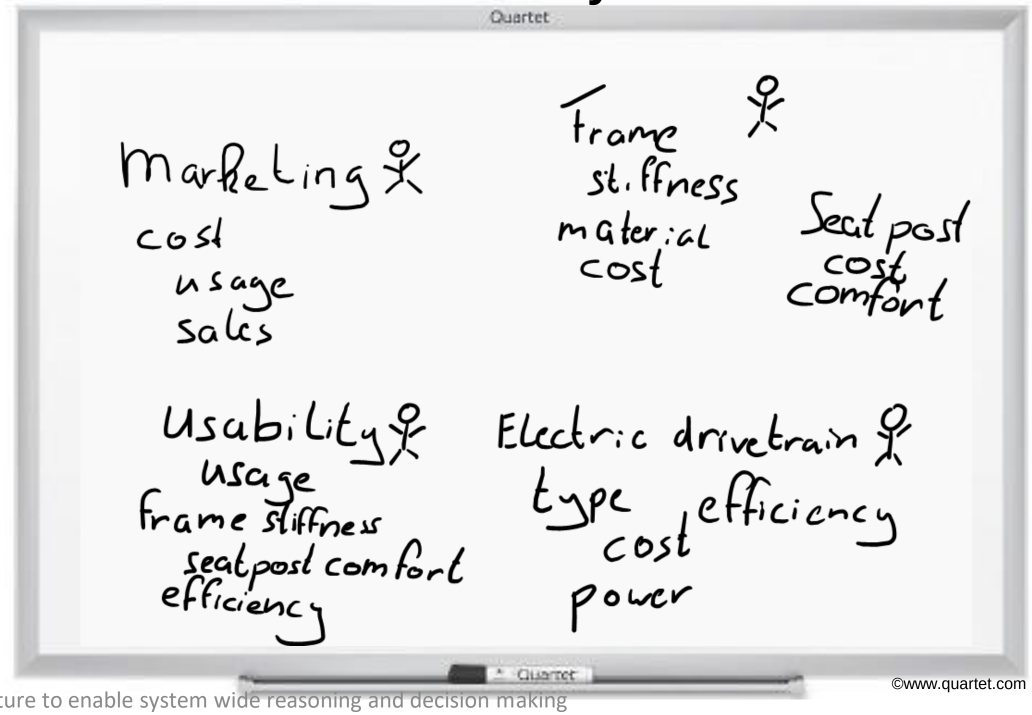
Electric bicycle case



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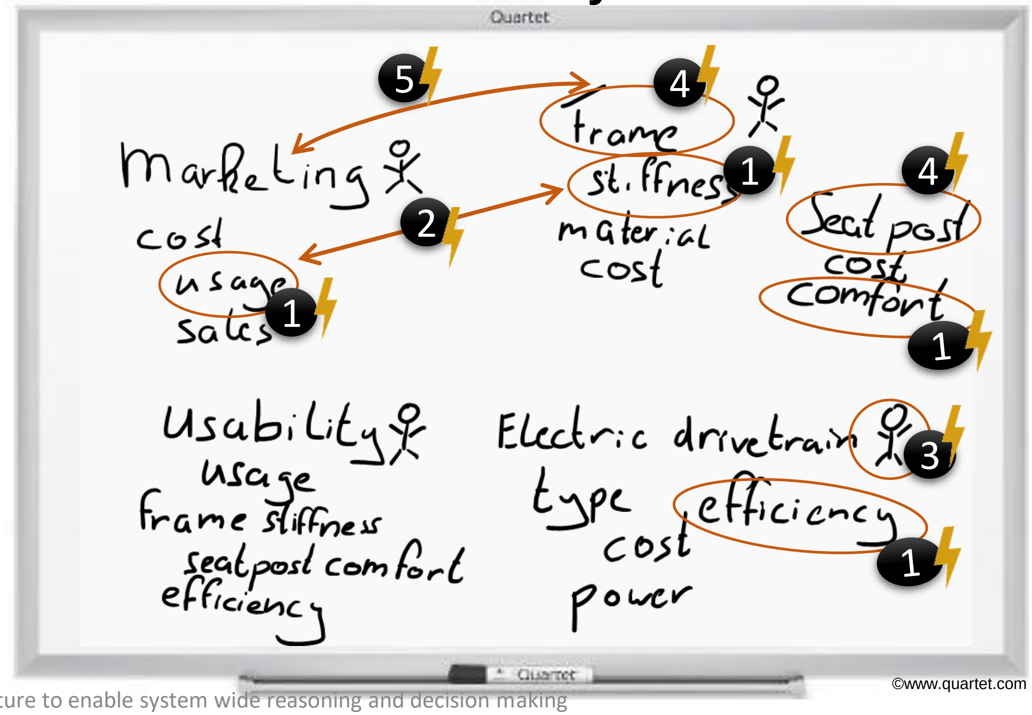
CONTEXT: DECOMPOSE SYSTEMS IN KNOWLEDGE DOMAINS

- Knowledge domain (KD): specific area of knowledge and information by a team

- Running example: electric bicycle case
  - Trade-off on cost and usage
  - Source of misunderstanding:
    1. Definitions or terminology
    2. Relations between knowledge domains
    3. Owner
    4. Knowledge domain scope
    5. Abstraction level

Electric bicycle case



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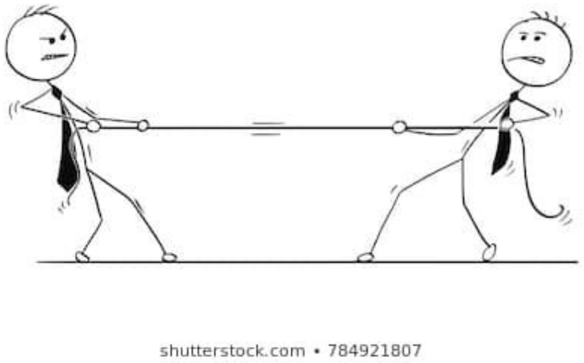
CONTEXT: REASONING, UNDERSTANDING, AND DECIDING IS THE CHALLENGE

- Other approaches
  - System architecting: provides multiple views but difficulties on making relations explicit
  - System designing: determine decision impact, but often lacks overview

- Challenge:
  - Reason, understand, and decide about the system-wide impact, whilst using explicit relation
  - Avoid sources of misunderstanding between knowledge domains to enable decisions



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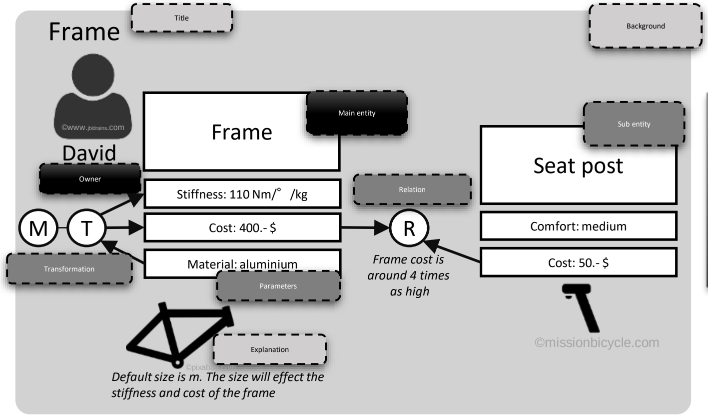
CONTEXT: OVERVIEW

Language elements
Block
Image
Text
Parameter
Model
Relation
Validation
Transformation

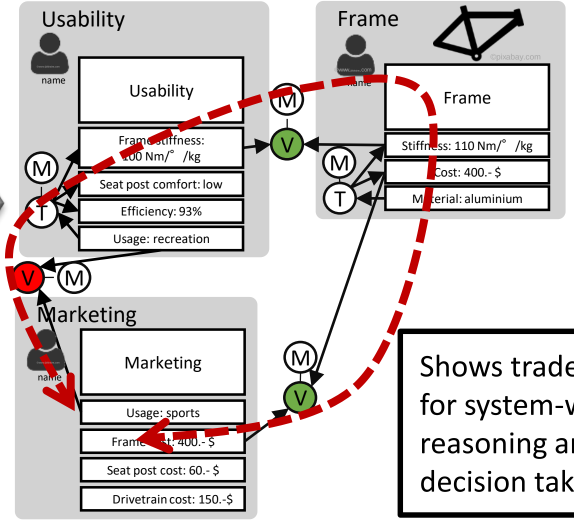
Describe Knowledge Domains

Knowledge domain pattern



Structure information

Knowledge domain Structure



Shows trade-off for system-wide reasoning and decision taking

- Contributions:
  - Multi-disciplinary architecture reasoning structure, with explicit relations, for system wide reasoning and decision making
  - Knowledge domain pattern, to capture essential information
  - Relations, for both qualitative and quantitative reasoning
  - Approach was investigated and validated in the industrial context of Océ professional printing systems

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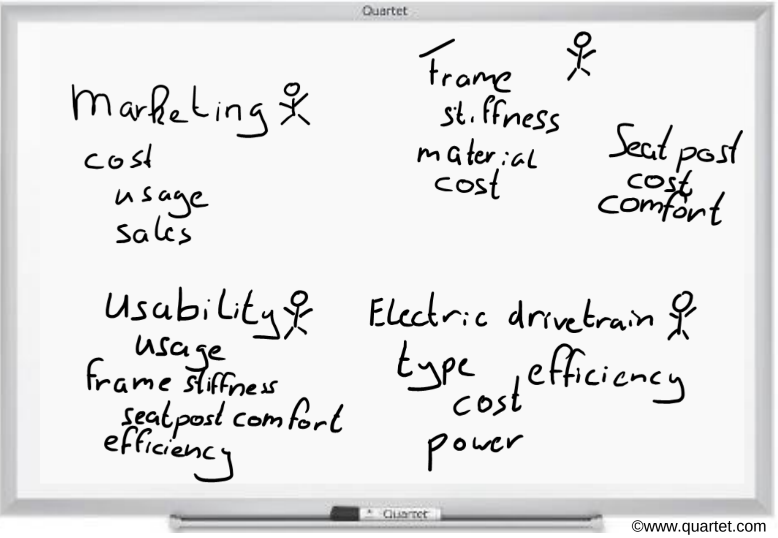
LANGUAGE ELEMENTS TO CREATE AN INFORMATION STRUCTURE

Electric bicycle case



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Structure information

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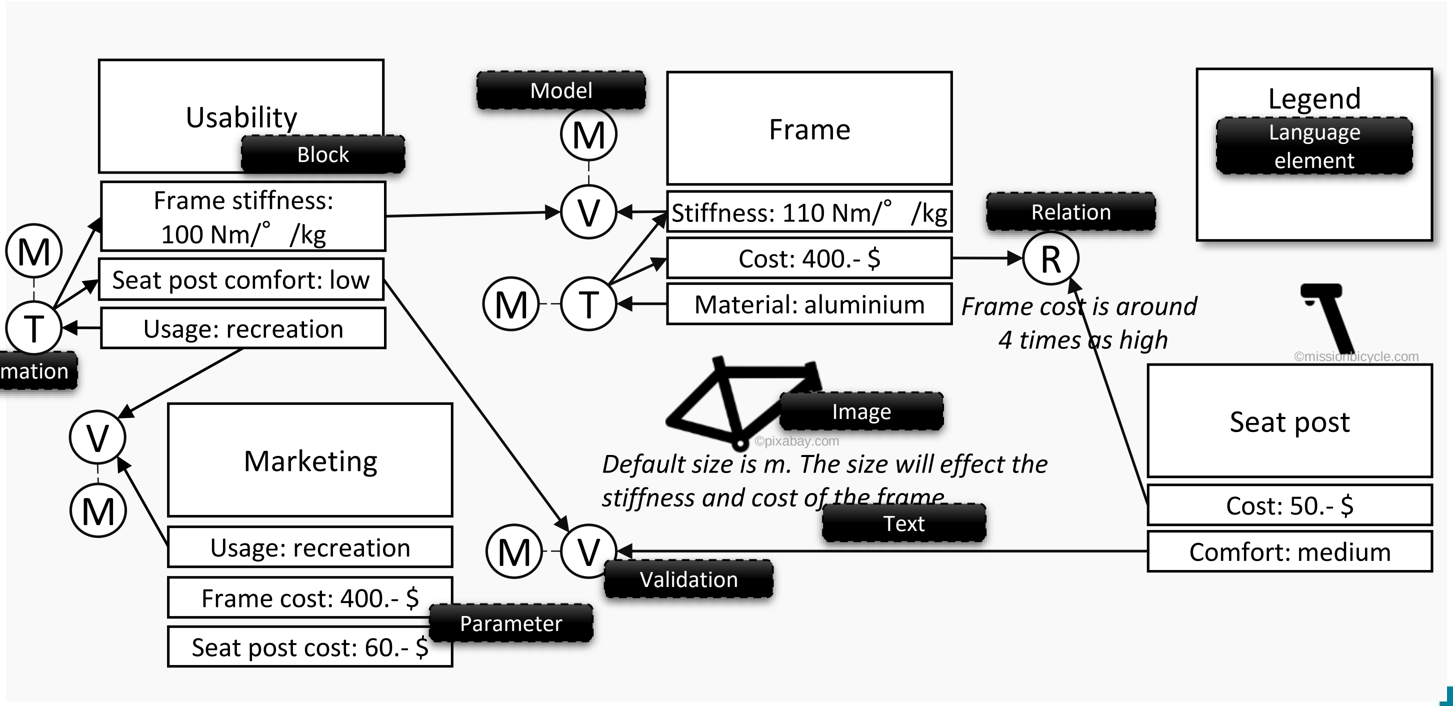
Information structure



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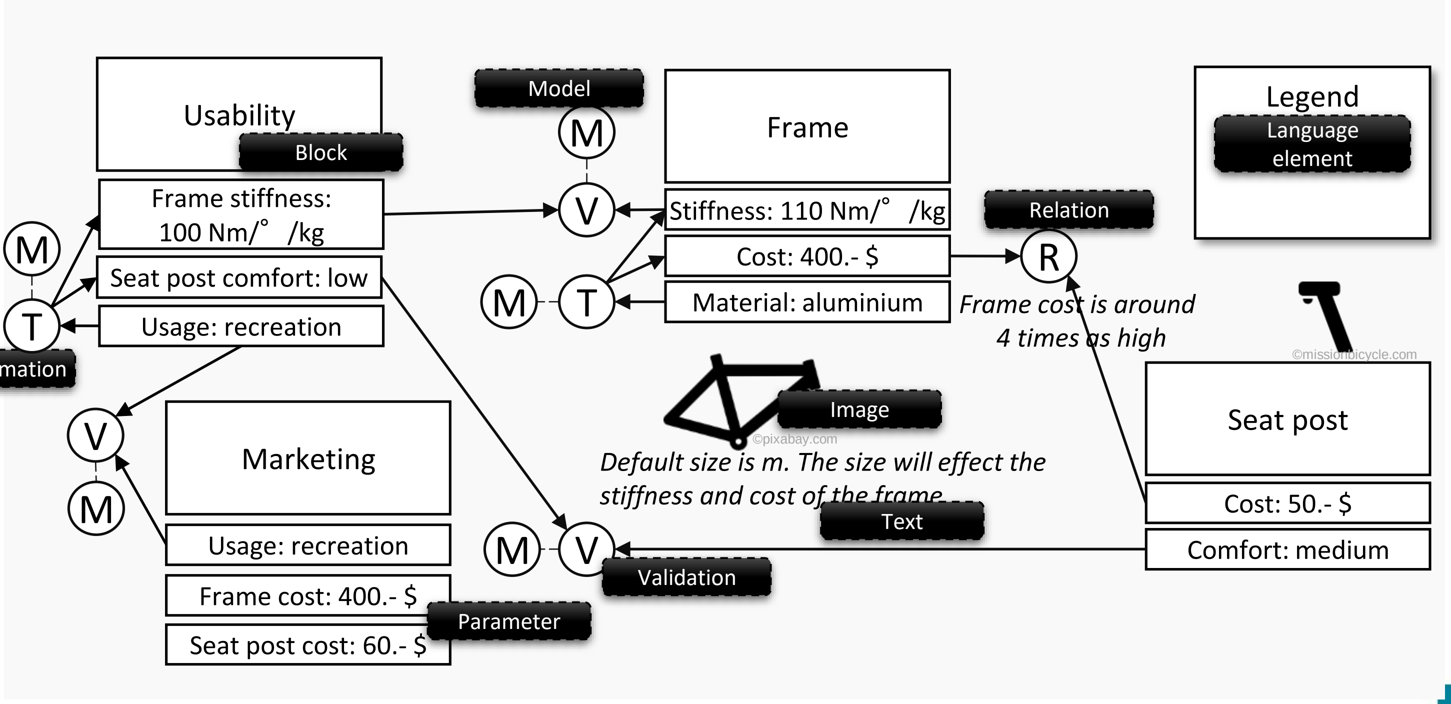
LANGUAGE ELEMENTS FOR QUALITATIVE AND QUANTITATIVE REASONING

Relate information:

- Relate qualitative
  - Relation R describe relations
- Relate quantitative
  - Transformations T and validations V between parameters
  - Model computes output values for transformation and validation

Information structure



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KNOWLEDGE DOMAIN PATTERN TO STRUCTURE INFORMATION

Architect and owner

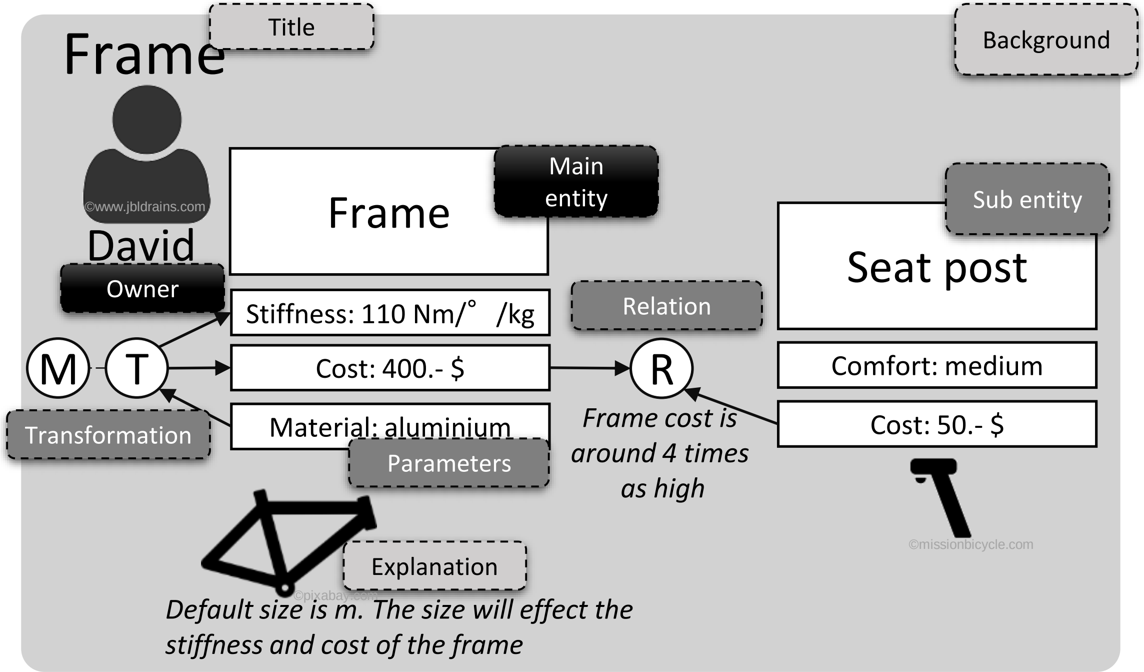
- Define the scopes of a knowledge domain via title and background
- Avoids misunderstanding via structured information

Pattern elements

Essential information

Advised information

Visual supportive information



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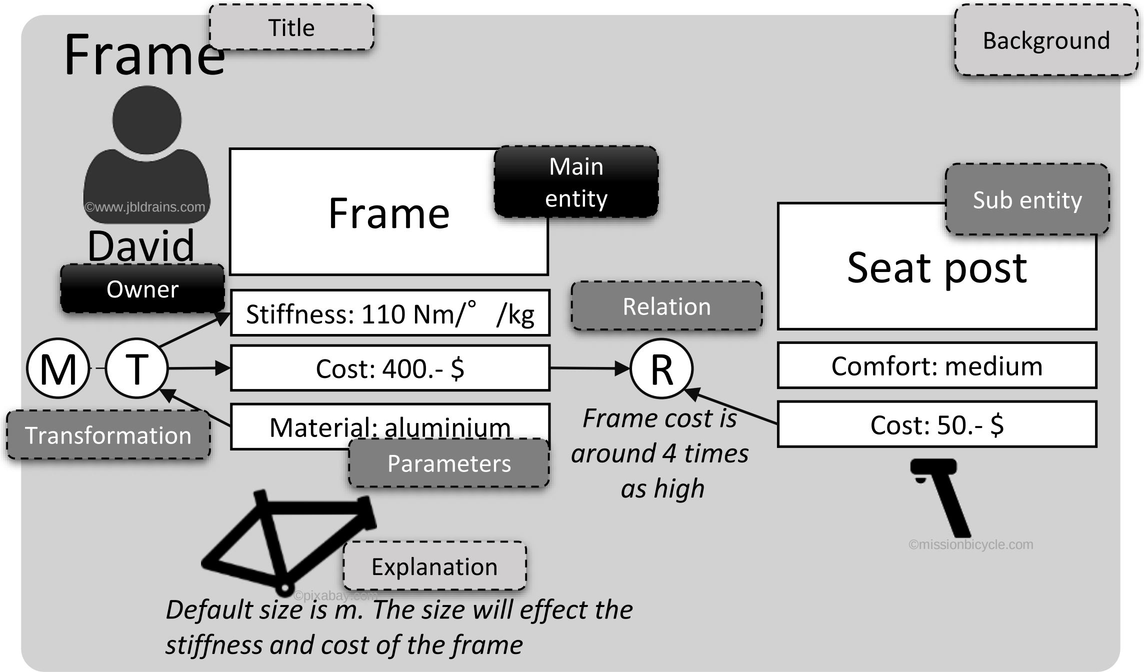
KNOWLEDGE DOMAIN PATTERN ENABLES OWNER TO REASON

Reasoning:

- Qualitative
  - Via relations between blocks or parameters
  - Owner decides if changes needed to changing input
- Quantitative
  - Via transformations between parameters
  - Owner searches input values that result in the desired output values
- Knowledge domain owner decides if changes are acceptable



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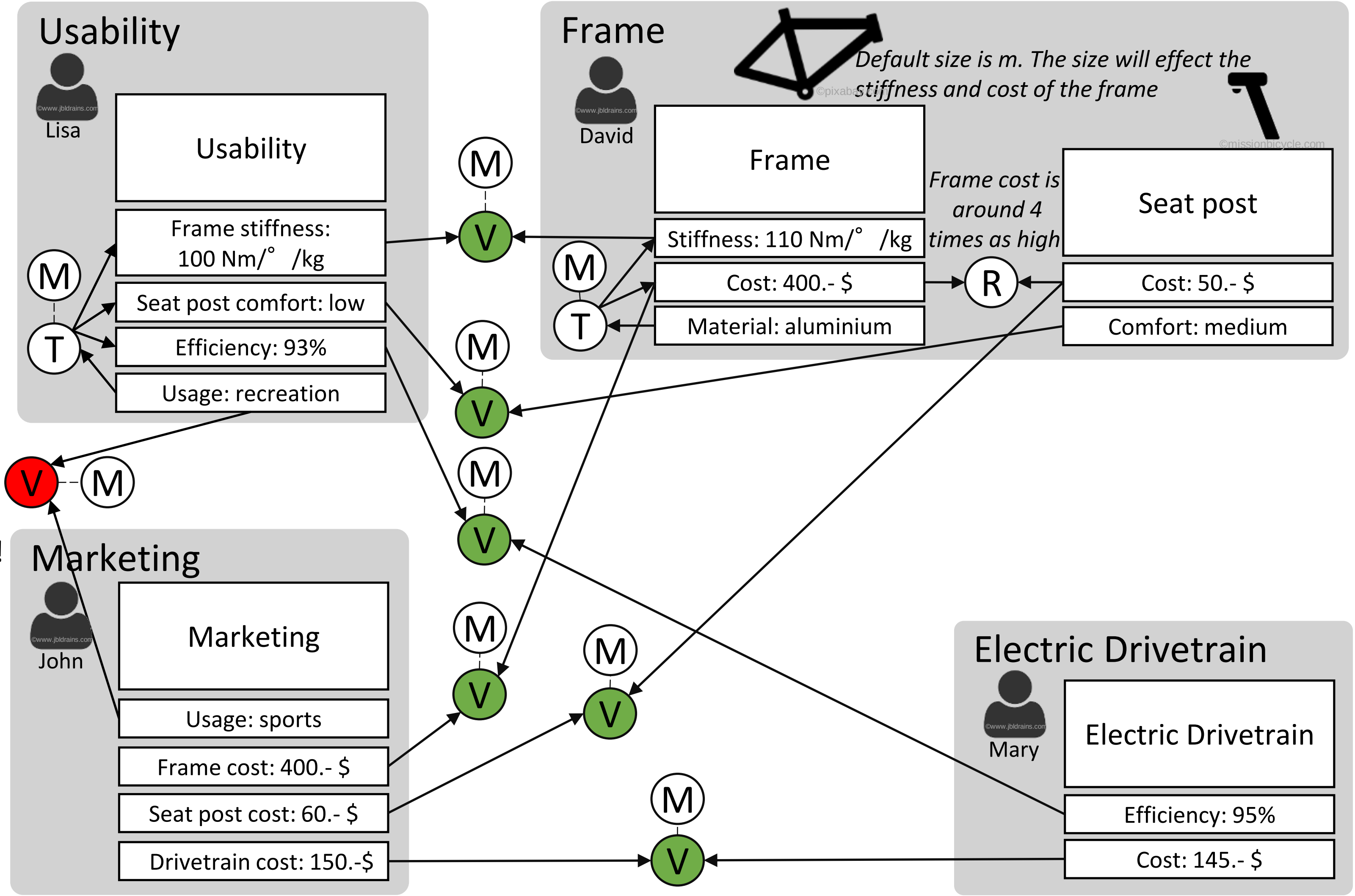
KNOWLEDGE DOMAIN STRUCTURE RELATES AND DECOUPLES

Relate knowledge domains (KDs)

- Validations decouple KDs
  - Colours shows agreement between KDs
  - Model is agreed contract between KDs
  - Observe impact of KD change on other KDs via validation
- **Qualitative** or **quantitative reasoning** over KDs on the impact of a change
- Absence of validation indicates KD isolation!



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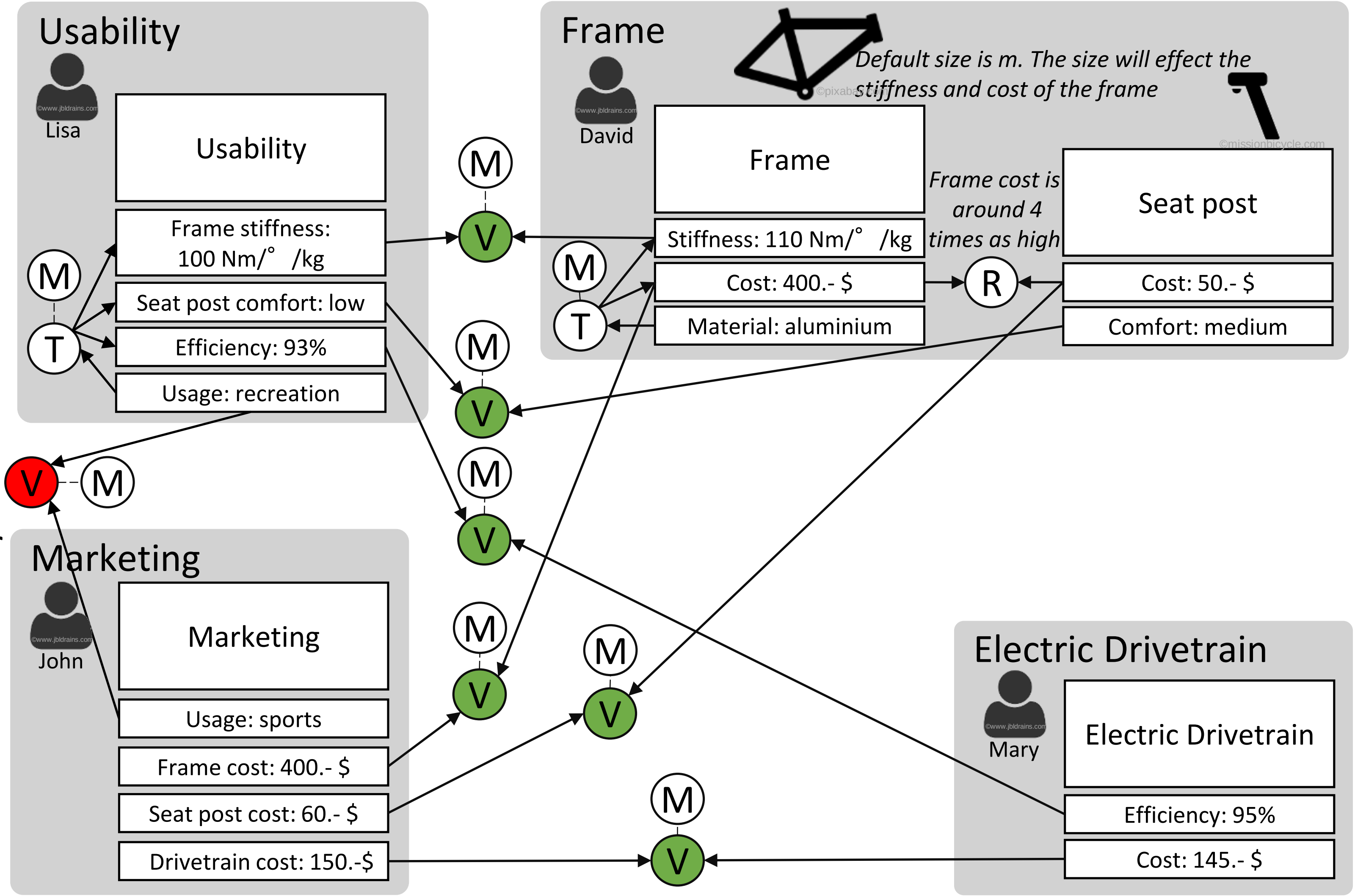
KNOWLEDGE DOMAIN STRUCTURE PROVIDES OVERVIEW TO THE ARCHITECT

Knowledge domain structure enables system wide reasoning

- Avoids misunderstanding
  1. Explicit definitions and terminology
  2. Relates knowledge domains
  3. Shows owner
  4. Provides knowledge domain scope
  5. Similar abstraction levels
- Enables trade-off investigation for architecture or design decisions



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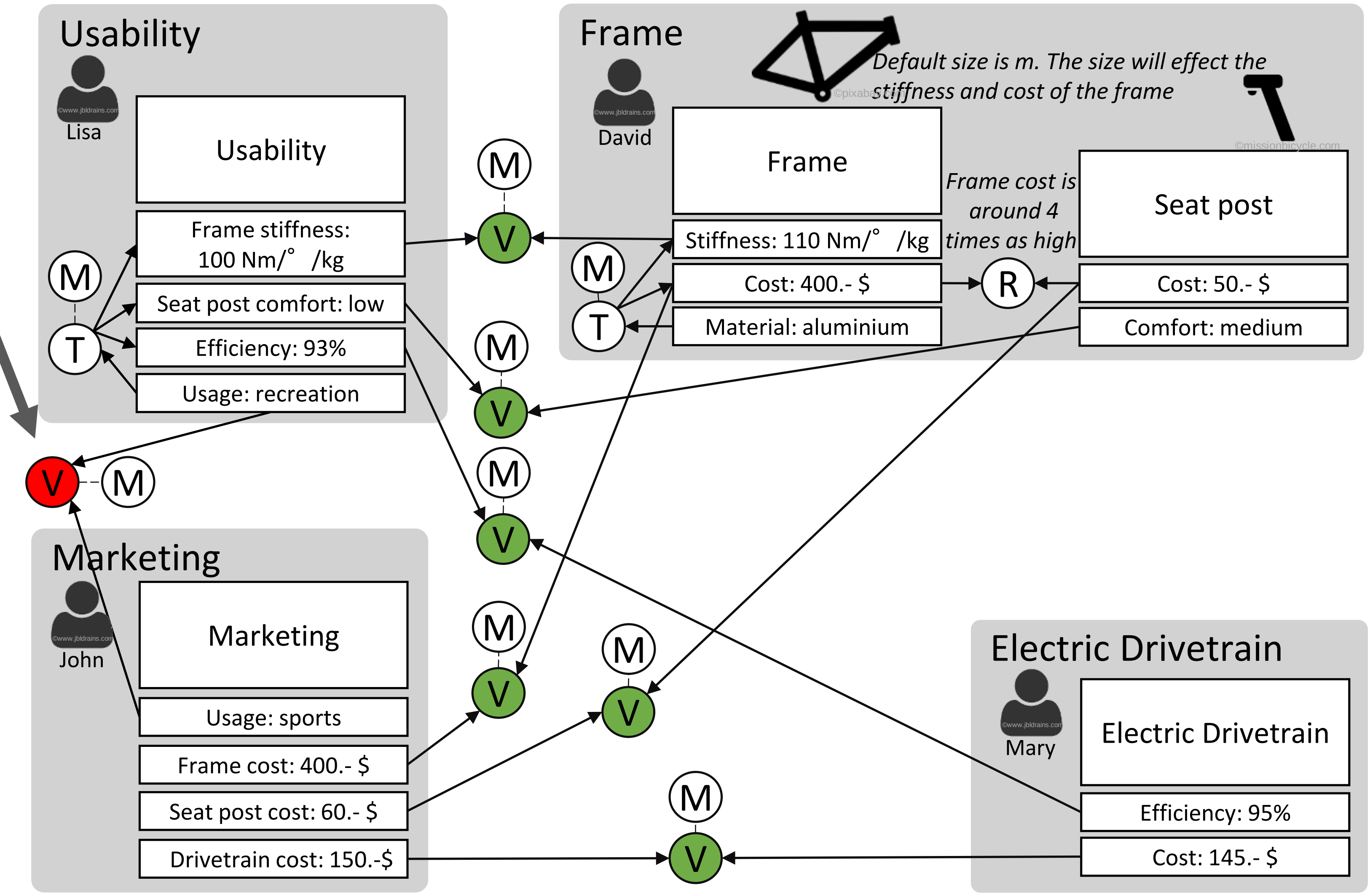
KNOWLEDGE DOMAIN STRUCTURE TRADE-OFF EXAMPLE

- Validation indicates disagreement "Marketing" and "Usability"
  - Architect can search solution and understand the trade-off



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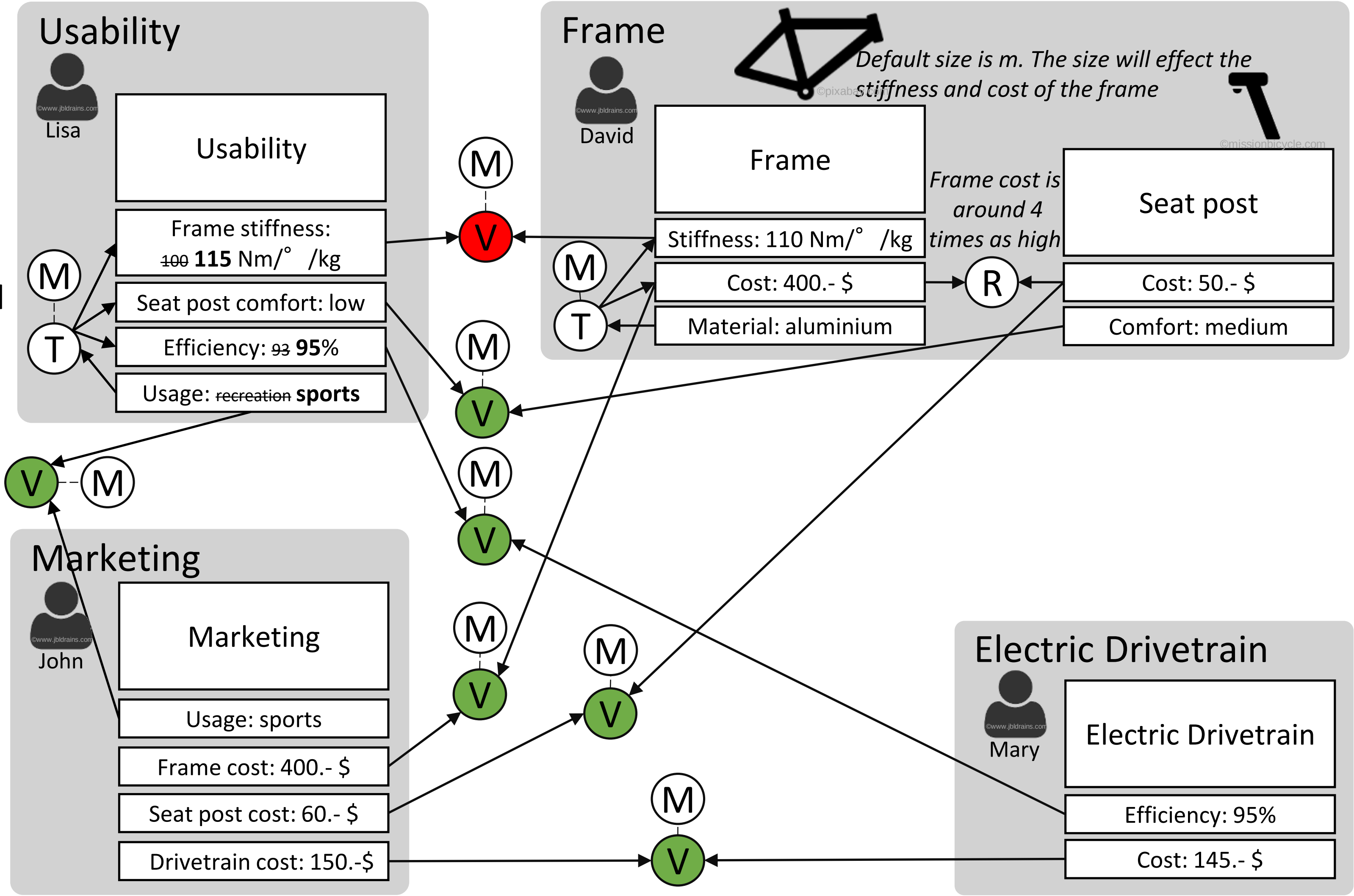
KNOWLEDGE DOMAIN STRUCTURE TRADE-OFF EXAMPLE

- Validation indicates disagreement "Marketing" and "Usability"
  - Architect can search solution and understand the trade-off
- Convince "Usability" knowledge domain to change
  - Validation between "Usability" and "Frame" shows disagreement



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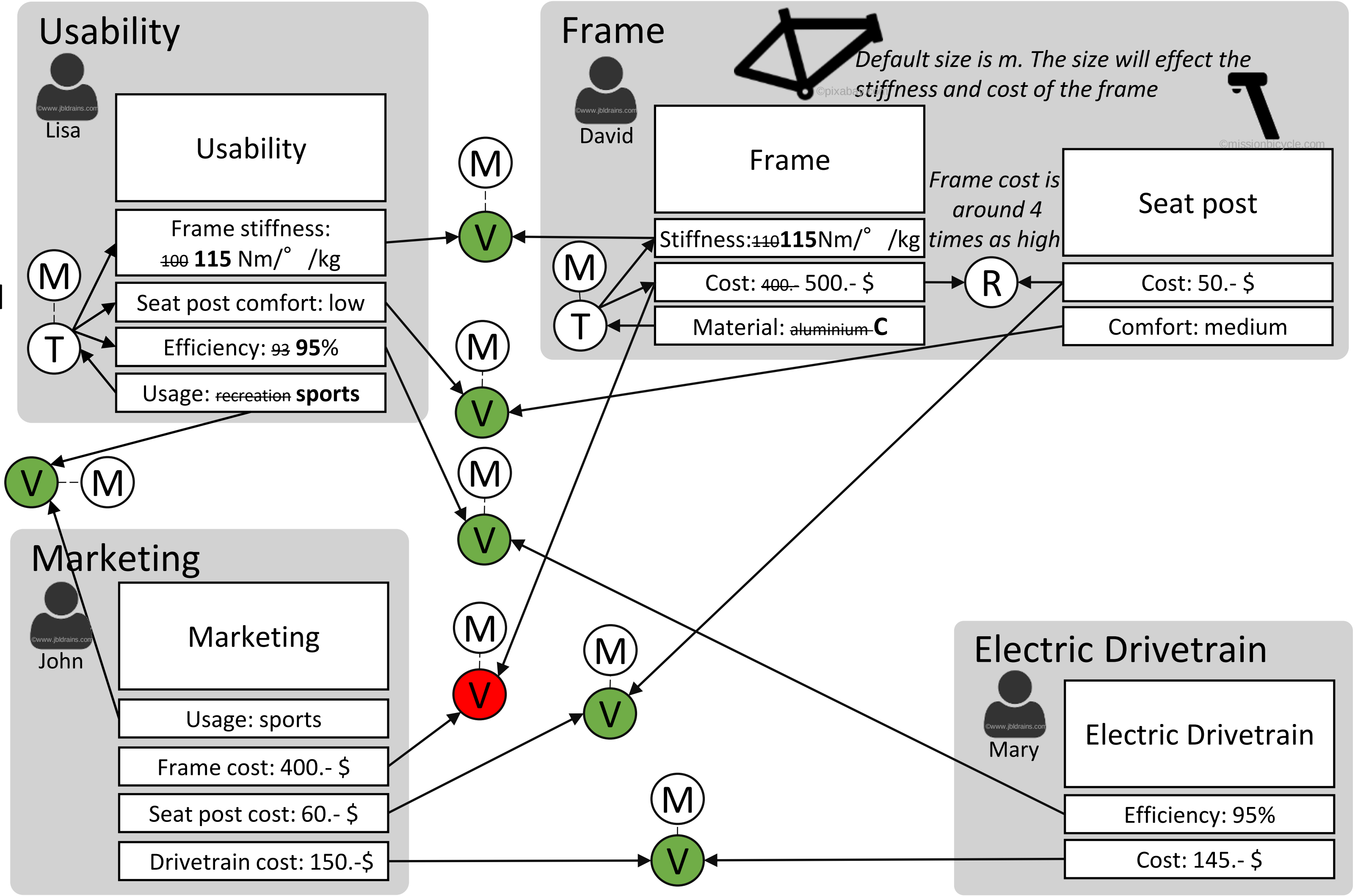
KNOWLEDGE DOMAIN STRUCTURE TRADE-OFF EXAMPLE

- Validation indicates disagreement “Marketing” and “Usability”
  - Architect can search solution and understand the trade-off
- Convince “Usability” knowledge domain to change
  - Validation between “Usability” and “Frame” shows disagreement
- Convince “Frame” knowledge domain to change
  - Validation between “Frame” and “Marketing” shows disagreement

Reveals “Marketing” internal trade-off between “Usage” and “Frame cost”

- Update targets
- Investigate alternative solutions for “Usability” or “Frame” knowledge domains



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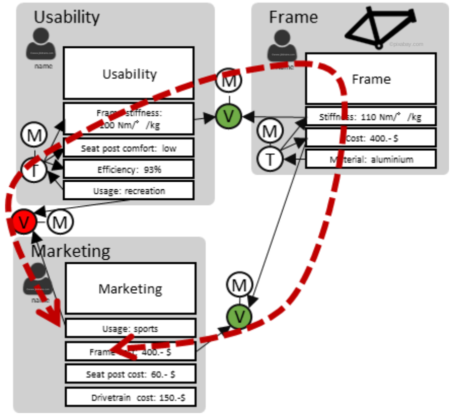
CONCLUSIONS

A multi-disciplinary knowledge domain structure to support architects for qualitative and quantitative system-wide reasoning

- Knowledge domain pattern to capture essential information
- Explicit relations inside and between the knowledge domains
  - Decouple knowledge domains by validations that indicate the level of agreement
  - Trade-offs are made visible to support decisions
- Stake holders are coupled to technology in a diagram reflecting the organization



- Future work: structures to support reasoning in large industrial systems with hundreds of knowledge domains

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QUESTIONS?

An initiative of industry, academia and TNO