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COMPONENT CLASSIFICATION: A CHANGE PERSPECTIVE

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1 INTRODUCTION

Component classification using Design Structure Matrices (DSMs) was recently developed to assess the modularity of components [1]. However, little effort has gone into component classification for designing product variants and freeze planning. In the design of a new product variant, decisions have to be made regarding which components should be carried over from the original product as common components [2] and which components need to be changed or frozen. Product variant planning can take place at the beginning of the design project to help the management shape the architecture of the product generation and at the end of the project to evaluate whether change strategies were carried out as planned for the new product variant. Freeze planning can also be used throughout the entire design process to freeze appropriate components whenever possible. Successful freeze planning is valuable as designers can reduce expensive change propagation by freezing components with high propagation risk early in the design process. Conversely, inappropriate freezing of a component with low propagation risk might constrain the design space unnecessarily. The management of product variants and freeze implementation is therefore vital to ensure the overall success of a product. In this paper, two component classification schemes, the Product Variant Portfolio and the Propagation Absorber/Multiplier Portfolio, are presented to identify components for new product variant and freeze planning from a change perspective which does not only use component connectivity for classification [1] but also direct and indirect change risks.

2 COMPONENT CLASSIFICATION USING CPM

The Product Variant Portfolio (PVP) and the Propagation Absorber/Multiplier Portfolio (PAMP) are two component classification schemes that make use of the information in the Change Prediction Method (CPM) tool [3]. The CPM is a tool for predicting change propagation risks based on product connectivity models which are stored and represented in DSMs. It utilizes risk values to draw designer's attention to high-risk change relations between components. The direct risk value is calculated as the product of the *likelihood* of a change occurring and the *impact* in terms of effort required to redesign the component of the subsequent change. The likelihood value and the impact value are both elicited from experienced designers. This information is used to compute combined risks between components by taking indirect change propagation into account. The incoming risk of a component is the sum of all the combined risk values that this component is changed due to changes in other components while the outgoing risk is the sum of all combined risk values resulting in a change to the component. The application of the PVP and the PAMP are to provide recommendations to designers during the design of product variants and freeze planning and are described in the following sections.

2.1 Component Classification for Product Variant Planning

The use of common components for new products is an on-going research topic [4]. Some recent researches look at embedding flexibility in product platforms to accommodate uncertain future market demands [2]. In this paper, a classification scheme based on a change perspective will be used to map components of the existing product onto the PVP and identify appropriate components for change strategies. An illustration of the PVP is shown in Figure 1a.

- Components that fall within the *Variant-Common* group, as the name suggests, are components that should be carried over directly into the new product without modification as these components have high incoming impact of change. Since the impact of change is high, modular design could be used if changes to these components are required so as to reduce future likelihood of change.

- The components that are in the *Variant-Modify* group are components with high incoming likelihood and low incoming impact of change. Since the impact of change is low, components in this group can be easily modified to meet the new design requirements. These components could be redesigned as flexible components if a change is required. This is to further reduce the impact of change as these components are very likely to be changed.
- Components that fall under the *General-Common* group are components with low incoming likelihood and impact of change. The components in this group are seldom changed and can be carried over directly into the new product. In addition, changes to these components can be easily carried out.
- Components in the *Non-Variant* group are components that have high likelihood of change and high impact when changed. Components in this group are unsuitable as carry-over components as changes are often unavoidable and costly. This provides an opportunity for implementing change strategies if a change is required for these components. There are 2 strategies for such components. The first one is for components with high outgoing risk to be redesigned with modularity, lowering incoming likelihood of change, to make them *Variant-Common* components. This is to ensure that these components will have less incoming likelihood of change in the subsequent product variants as it is difficult to change. The second strategy is for components with low outgoing risk to be redesigned with flexibility, lowering incoming impact of change, to make them *Variant-Modify* components. This is to ensure that these components are easier to change for subsequent variants. Successful implementation of flexibility and modularity will shift components from the *Non-Variant* group into the *Variant-Modify* and *Variant-Common* group, respectively, in future mapping.

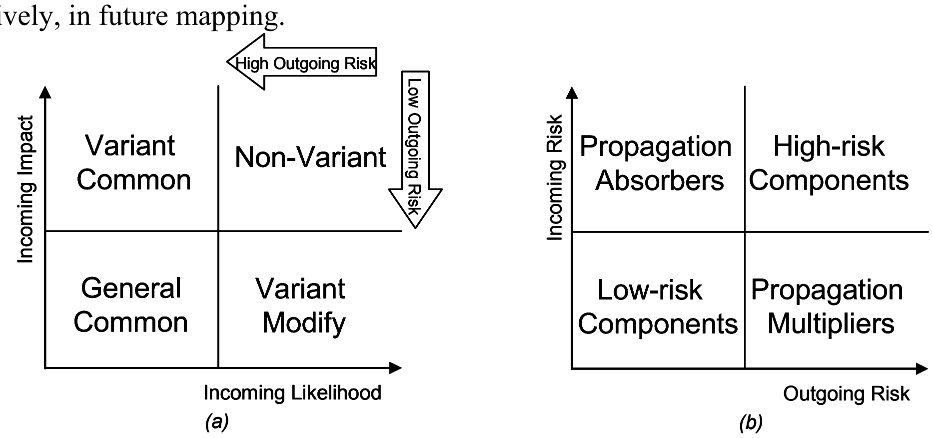

Figure 1.(a) Product Variant Portfolio and (b) Propagation Absorber/Multiplier Portfolio

The rationale in the PVP to make components with high outgoing risk more modular instead of more flexible is due to the fact that components with high outgoing risk affects other components more than those with a low outgoing risk. By making these components modular, designers can freeze them early in the design process whenever possible for future product variants.

2.2 Component Classification for Freeze Planning

Freezes play an important role in the development of a product [5]. It is an agreement between two or more parties on the current design state and can serve as a basis for further development or as a design end point to hand over for production. The implementation of freezes can be due to manufacturing lead time or to reduce the potential of further product changes. The timely application of freeze strategy can prevent components that are likely to multiply a change to be frozen early in the design process. The identification of change multipliers and absorbers [6] is therefore imperative in a design project. A component classification scheme that is based on risk can also be used to support freeze planning [7]. Figure 1b shows the PAMP which maps components according to change risk.

- The components in the top-left quadrant have a small effect on other components but have a high risk of being changed by changes to other components. These are known as *Propagation Absorbers*.
- Components in the bottom-right quadrant are *Propagation Multipliers*. These are components that are rarely affected by other components, but changes to them require potential redesign to a

number of other components.
- The components in the bottom-left quadrant are components that have a generally low impact. These are termed as *Low-risk Components*.
- Components that are both affected by other components and affect other components are in the top-right quadrant. These components are termed as *High-risk Components*. These components will require very high attention from the designers as their behavior cannot be easily predicted.

By referring to the PAMP, designers can structure the design process to freeze *Propagation Multipliers* whenever possible. As more components are frozen towards the end of the design process, the design space will gets more constrained with respect to time. Designers can select components with the least propagation risk in a time-specific situation by referring to the PAMP. For example, if a design solution is unsuccessful during the design process, designers can identify possible design alternatives by referring to the PAMP and consider unfreezing components that are *Low-risk Components* and *Propagation Absorbers* as the risk of change propagation for these components are lower. A more powerful application can be achieved by combining the information provided in both the PVP and the PAMP to converge a set of possible solution alternatives. For example, components that do not fall within the *Propagation Multipliers* quadrant can be captured in the *Variant-Common* quadrant and be frozen early in the design process to redirect resources and decrease project uncertainties.

3 CONCLUSION

Two component classification schemes based on a change propagation perspective were presented in this paper to support the planning for product variants and component freeze orders. The Product Variant Portfolio was developed to help designers identify components for change strategies while the Propagation Absorber/Multiplier Portfolio helps to indicate components that could be frozen early in the design process. More effort should be placed on critical components. Using both the Product Variant Portfolio and the Propagation Absorber/Multiplier Portfolio allows designers to make better decisions on which components to be redesigned in case changes to the product have to be implemented.

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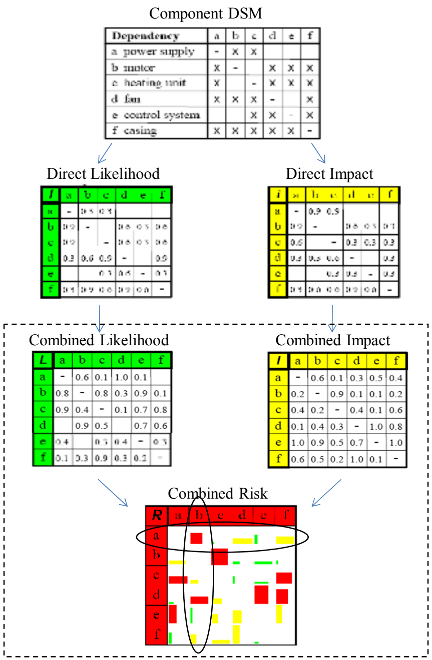
Introduction

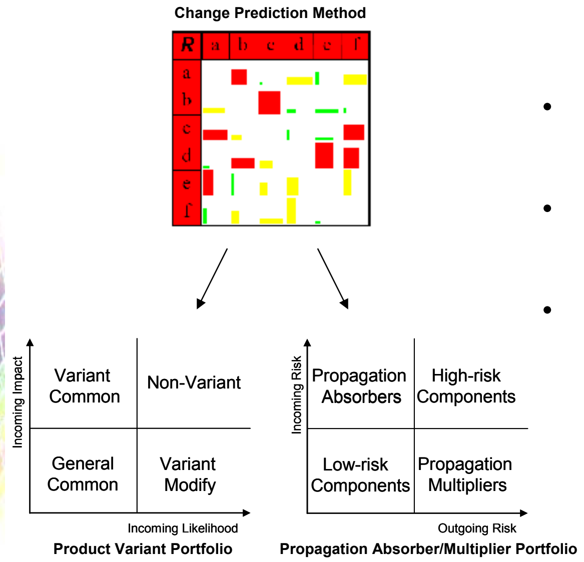
- Planning of new product variant involves different levels of the organisation
- Planning can involve the shaping of the product architecture and the sequencing of components to be designed
  - components to be carried over
  - components to be designed early
- Two component classification schemes, the *Product Variant Portfolio* and the *Propagation Absorber/Multiplier Portfolio*, are introduced to aid these planning processes from a change perspective.

Change Prediction Method



- CPM predicts change risks based on DSMs
- Draws designer's attention to high-risk components
- *risk* = *likelihood* x *impact*
- Combined risks using indirect change propagation
- Incoming risk of a component = ∑(combined risks in a row)
- Outgoing risk of a component = ∑(combined risks in a column)

Component Classification



- The *PVP* and *PAMP* are based on the CPM risk analysis
- The PVP identifies components for change strategies
- The PAMP identifies components for freeze strategies

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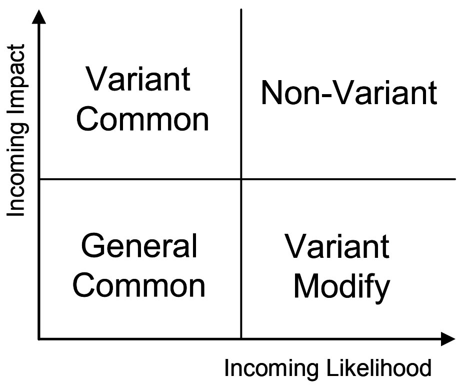
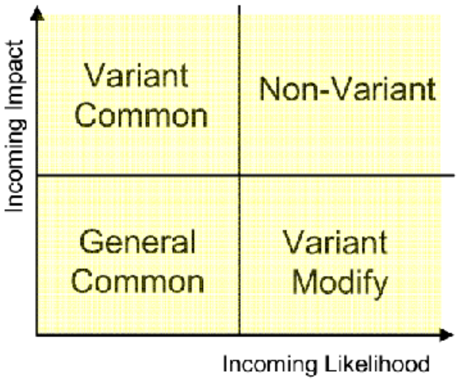
Product Variant Portfolio



- Classifies components in terms of incoming likelihood & impact
- Recommend change strategies for new product variant
- Evaluation for platform strategy
- Initial platform strategy irrelevant for legacy products
- Components shift if design margins are changed

Product Variant Portfolio



- ***Variant Common***
  - Unlikely but difficult to change
  - Reduce connectivity
- ***Variant Modify***
  - Likely but easy to change
  - Increase flexibility
- ***General Common***
  - Unlikely and easy to change
  - Suitable to be carried over without modification
- ***Non-Variant***
  - Likely and difficult to change
  - Increase flexibility for low outgoing risk
  - Reduce connectivity for high outgoing risk

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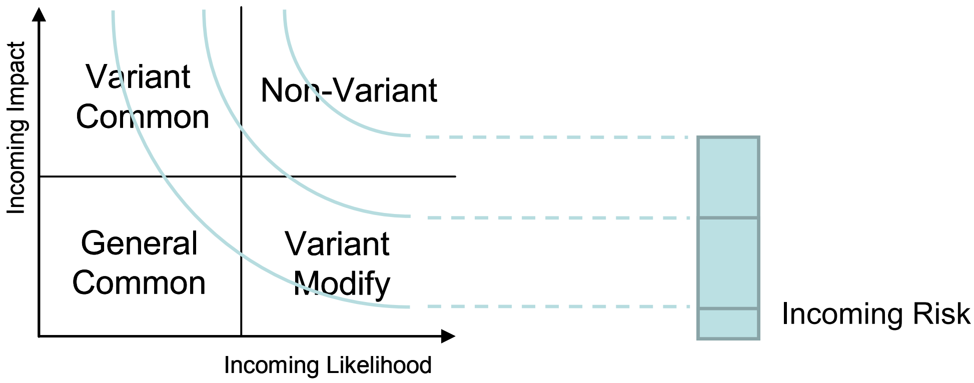
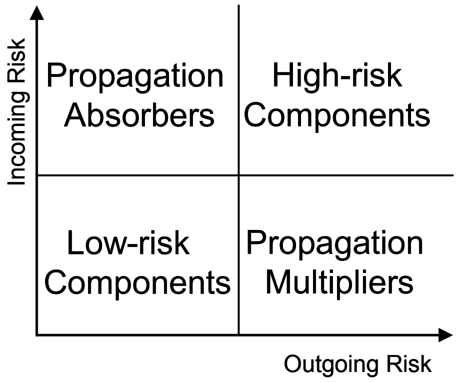
Change Risk



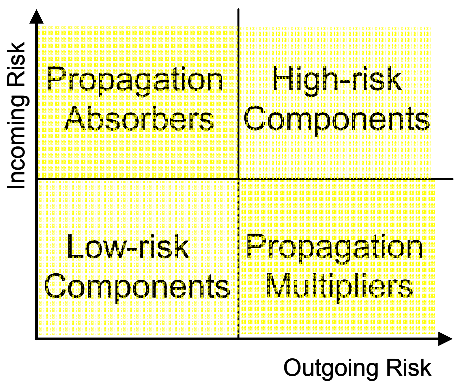
- The PVP considers the likelihood & impact to change
- Indicates the incoming risk
- Local analysis
- Outgoing risk indicates influence on others
- Includes outgoing risk for global analysis

Propagation Absorber/Multiplier Portfolio



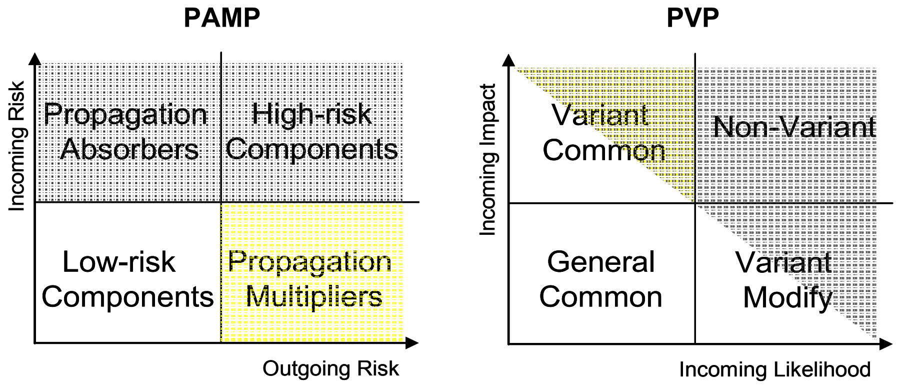
- Classify components by risk
- Provide freeze strategies
- Freeze can be due to
  - manufacturing lead time
  - Reduce further changes
- Freeze components that are likely to multiply changes early
- Unfreeze components with the least outgoing risk during rework

Propagation Absorber/Multiplier Portfolio



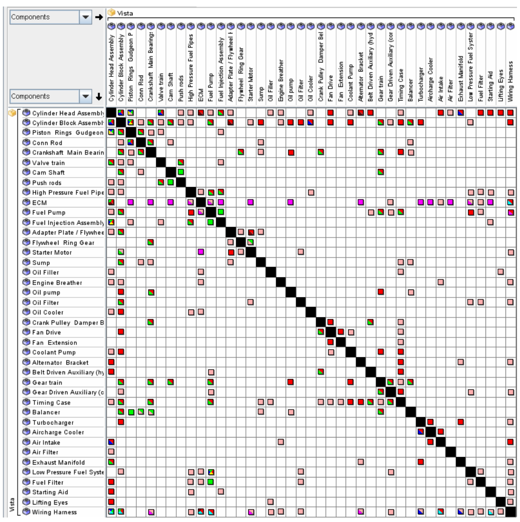
- ***Propagation Absorbers***
  - Small effect on others
  - High risk of being changed
  - Delay Freeze
- ***Propagation Multipliers***
  - Rarely affected by others
  - Strong effect on others
  - Frozen early
- ***Low-risk Components***
  - Low influence on others
  - Seldom affected by others
  - Least critical components
- ***High-risk Components***
  - Strong effect on others and by others
  - High attention required

Converging Design Solutions



- Combine PVP and PAMP to converge solutions
- Freeze appropriate components early
- Redirect resources and decrease project uncertainties.

Example: Diesel Engine



Component DSM

- DSM to capture connectivity
- Product breakdown to 41 components
- 14 core components
- Change likelihood and impact obtained from a team of engineers
- Compute direct and indirect risk

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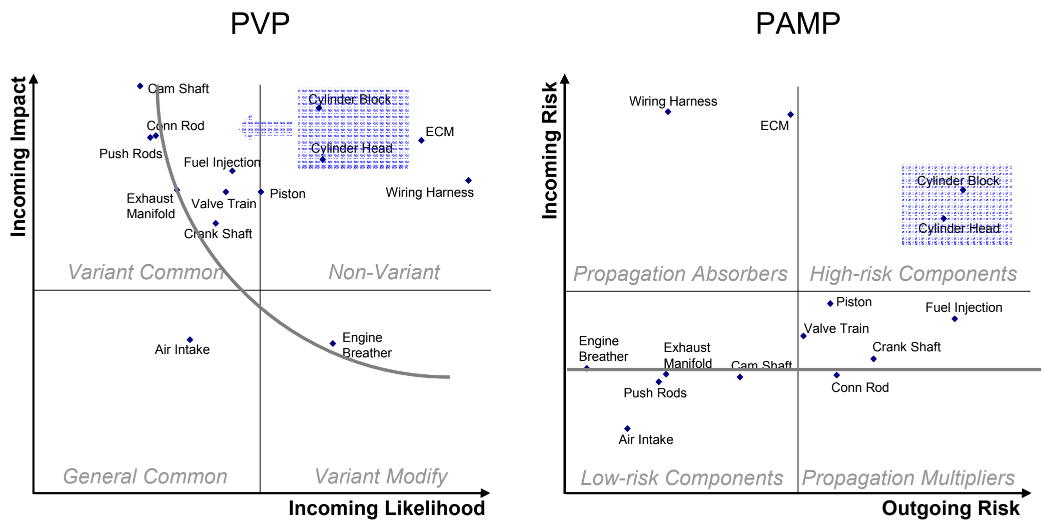
Example: Diesel Engine



- Unwise to freeze early
- Reduce change likelihood by high design margin
- Reduce connectivity

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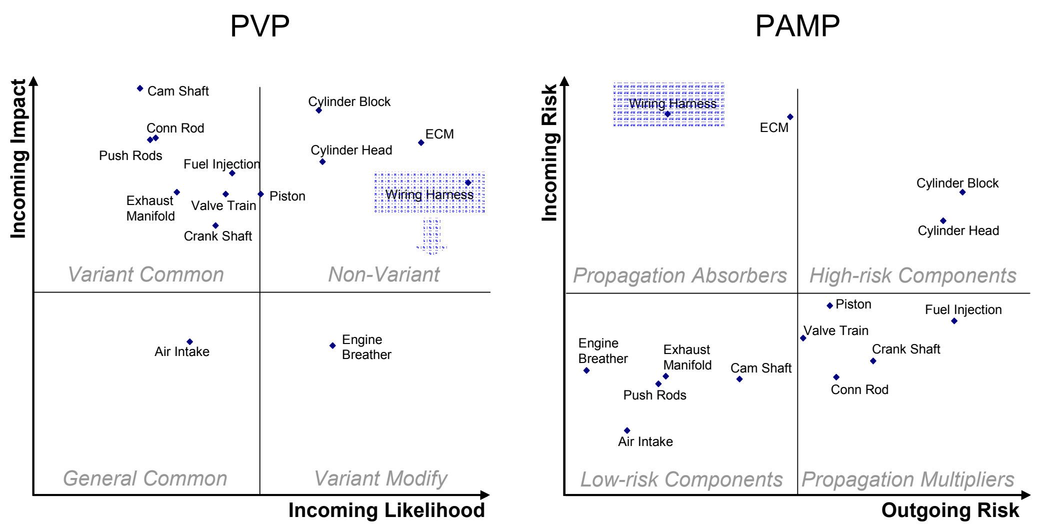
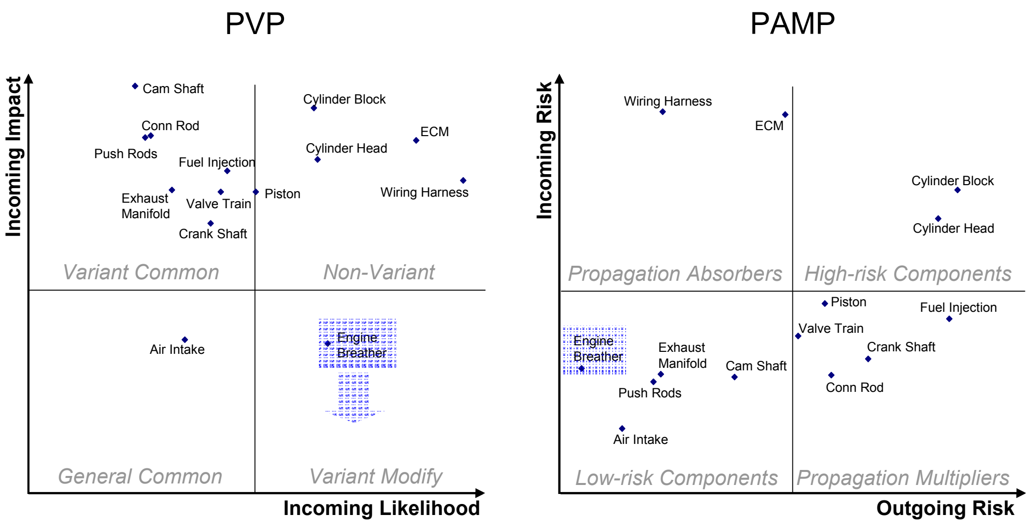
Example: Diesel Engine



- Most likely to be changed
- Impact relatively high
- Design with flexibility

Example: Diesel Engine



- Likely to be changed
- Design with flexibility
- Reduce change impact for future product variants
- Reduce Cost?

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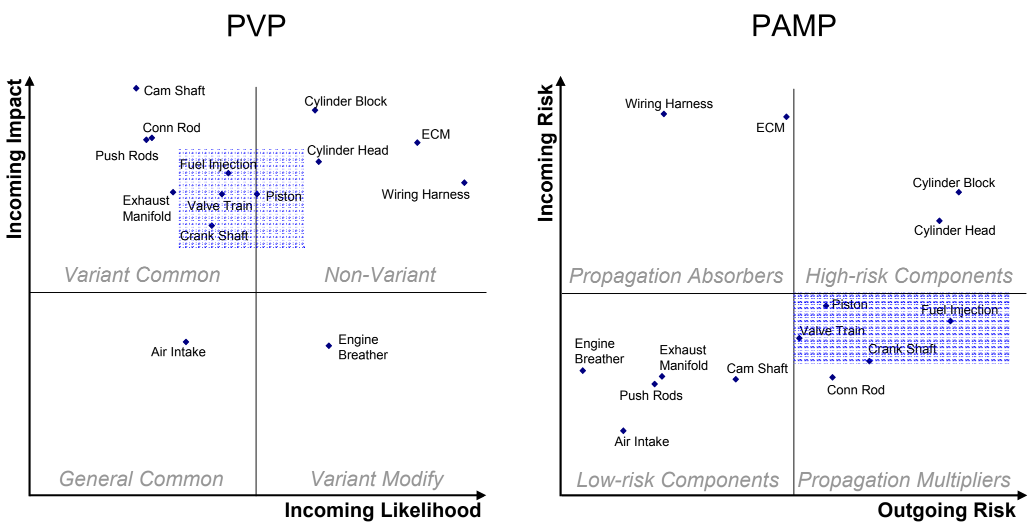
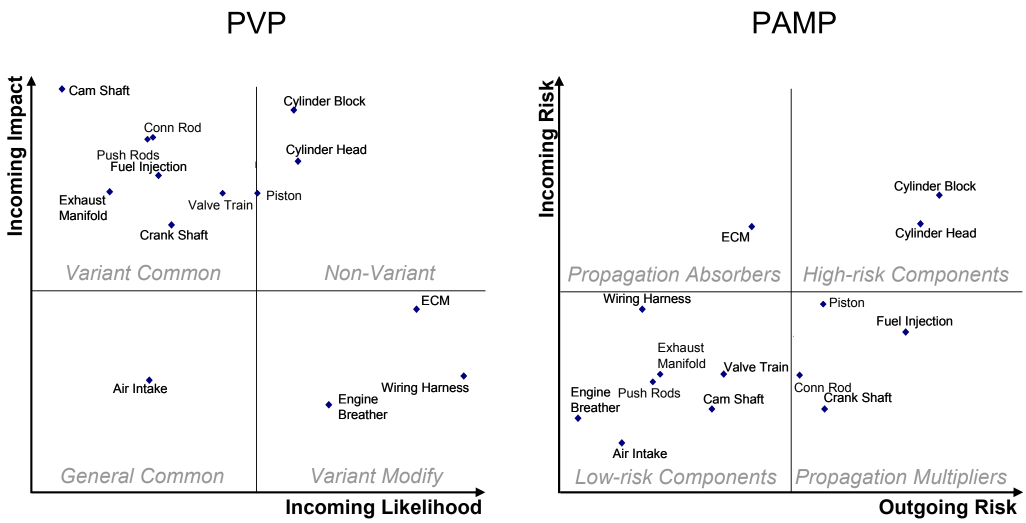
Example: Diesel Engine



- Components near high risk quadrants
- Likelihood can increases as design margin depletes
- Indication for new product generation?

Example: Diesel Engine



- Decrease incoming change risk
- Indirectly decrease outgoing risk
- Not all components are suitable candidates

Summary

- Two component classification schemes based on components DSM were introduced
- Provide information and strategies from a change perspective
  - PVP identifies components for change strategies
  - PAMP indicates components that could be frozen early
- Help designers plan for new product variants
- Both schemes can be used concurrently to provide more insights