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PLM ESSENTIALS

6. ENGINEERING CHANGE MANAGEMENT (ECM)

QR_

CONTENTS

6 ENGINEERING CHANGE MANAGEMENT

At the heart of all complex engineering and associated manufacturing processes is Product Data Management (PDM) - the business function that organises, maintains and reports all product data.

PLM captures and tracks information on the individual parts, components and modules that constitute a finished product throughout its lifecycle, including changes made during development.

This includes part numbers, supplier details, CAD drawings and more, with everything stored in a database easily accessible to the likes of project managers, engineers, salespeople, purchasing and QA teams.

Efficient management of product data helps develop products quicker, get them to market faster, and push costs down.

ENGINEERING CHANGE MANAGEMENT

TRACKING PART DESIGN CHANGES FROM START TO FINISH

Since nothing stands still for long in the automotive world, product changes are ongoing.

The easiest way to manage ever-evolving part design changes – from highlighting their need, to tracing and auditing their usage at the end of the process – is with a robust Engineering Change Management process.

To provide an overview of an effective and robust process, we're exploring one created for an electric vehicle manufacturer.

WHAT IS ENGINEERING CHANGE MANAGEMENT?

At a high level, change management is the tracking and control of changes to a product, organisation, process, system, document, or any other business entity.

A successful change management process will satisfy some core requirements:

- **Establishing stakeholder needs and a business case for their fulfilment**
- **Monitoring risks, benefits, costs and dependencies associated with change**
- **Tracking and communicating progress**
- **Defining the required decision making and implementation activities**

In an engineering context, there are typically three areas: changes to part design (Engineering Change Management), changes to product configuration (Configuration Change Management) and physical part implementation (Change Control).

ENGINEERING CHANGE MANAGEMENT

Engineering Change Management (ECM) is the process by which changes to the attributes of a physical part, system or associated document are managed. It is through this process that the business case for a design change is captured, its impact evaluated, key stakeholders are aligned and finally, the decision to implement the change is taken.

Once a design change is understood, agreed, documented and released, then the ECM process is complete and the Change Control process handles the workstreams related to the actual implementation of the change into the physical product.

CONFIGURATION MANAGEMENT

Configuration management is the control and deployment of changes to orderable configurations or variations of a product, and the part content of each configuration.

While these changes may drive, or be driven by, design change, the design changes themselves must still be managed using an ECM process. Configuration management supports ECM by providing the structure through which many variants can be managed within a single project, reducing administration and duplication.

CHANGE CONTROL

Change Control is typically a downstream function from ECM, which captures, tracks and organises all the necessary activities needed to implement a change with minimal negative impact to production. While decisions are taken within the Change Control process, these typically relate to exact timing, location and logistics, as the business case is already set and agreed as part of the ECM process.

CHANGE REGISTER, RISK AND OPPORTUNITY

All change management systems ultimately rely on some form of change register alongside a Risk and Opportunity Register (ROR), which together provide a clear overview of changes in progress and possible future changes.

ECM is no different, and owing to the cost, weight and timing-sensitive nature of engineering projects and the complexity of the end products, the change register is often a complex system in its own right.

In all commercial automotive engineering businesses, the change register is far from a simple list. Typically, it's an entire system, comprising different objects tracking different stages of the change (Engineering Records, Change Requests, Change Orders, etc.) and providing an integrated electronic system for capturing approvals.

But the key functionality of a change register must not be lost – its primary purpose is to record and clearly communicate the progress of each proposed change through the process.

ECM SUITABILITY

ECM processes vary across the engineering industry because they are driven by the unique demands of each market sector, whether financial or regulatory. Each process is a careful trade-off between speed, workload and quality.

The overall cost must be assessed, including the resource needed to manage the process, the cost of errors and the overall time to market. Heavily regulated, safety-critical industries, such as aerospace, tend to opt towards much more stringent processes as the results of an error could potentially be catastrophic.

Those industries in which the potential impact of an issue reaching customers, or where being first to market is important, may opt for speed and efficiency over robustness.

Choosing the correct balance – and being willing and flexible to update that balance as circumstances change – is vital to ensuring continued success.

SOFTWARE CHANGE MANAGEMENT

Any item that progresses through the ECM process can typically be decomposed into multiple smaller changes that together define the gap from a previous revision of a component to the proposed new revision.

Managing these smallear changes individually is not always necessary, as it is only the discrete revisions of a given component that can ever exist, but all changes must be captured against that ECM item.

Traditionally, all changes can be managed in the same way, but with the increasing quantity and complexity of software in modern products – and the nature of software development itself – an extra level of process is needed.

Typically, software will be revised many times and be extensively tested before a version of it is installed into any physical product. Using the complete machinery of ECM for each iteration quickly becomes cumbersome and adds very little value to the finished product – the only versions of software that must be properly controlled are those released to production, but at the same time, each change must be well documented.

As a result, a separate, lightweight change register and process is needed for software development, with only the versions to be used in finished products (prototypes or otherwise) to undergo the full ECM process.

Finding the balance between these two extremes is critical so that an ECM can respond quickly to change but is robust enough to make sure business areas are not heavily impacted by any changes made.

WHO USES ENGINEERING CHANGE MANAGEMENT?

Since a change to any part will have an impact in all areas of the business, departments affected by ECM include:

- **Engineering**
- **Purchasing**
- **Homologation**
- **R&D**
- **Suppliers**
- **Manufacturing/Production**
- **Logistics**
- **Styling/Concept**
- **Finance**
- **Quality**

ENGINEERING CHANGE MANAGEMENT IN PRACTICE

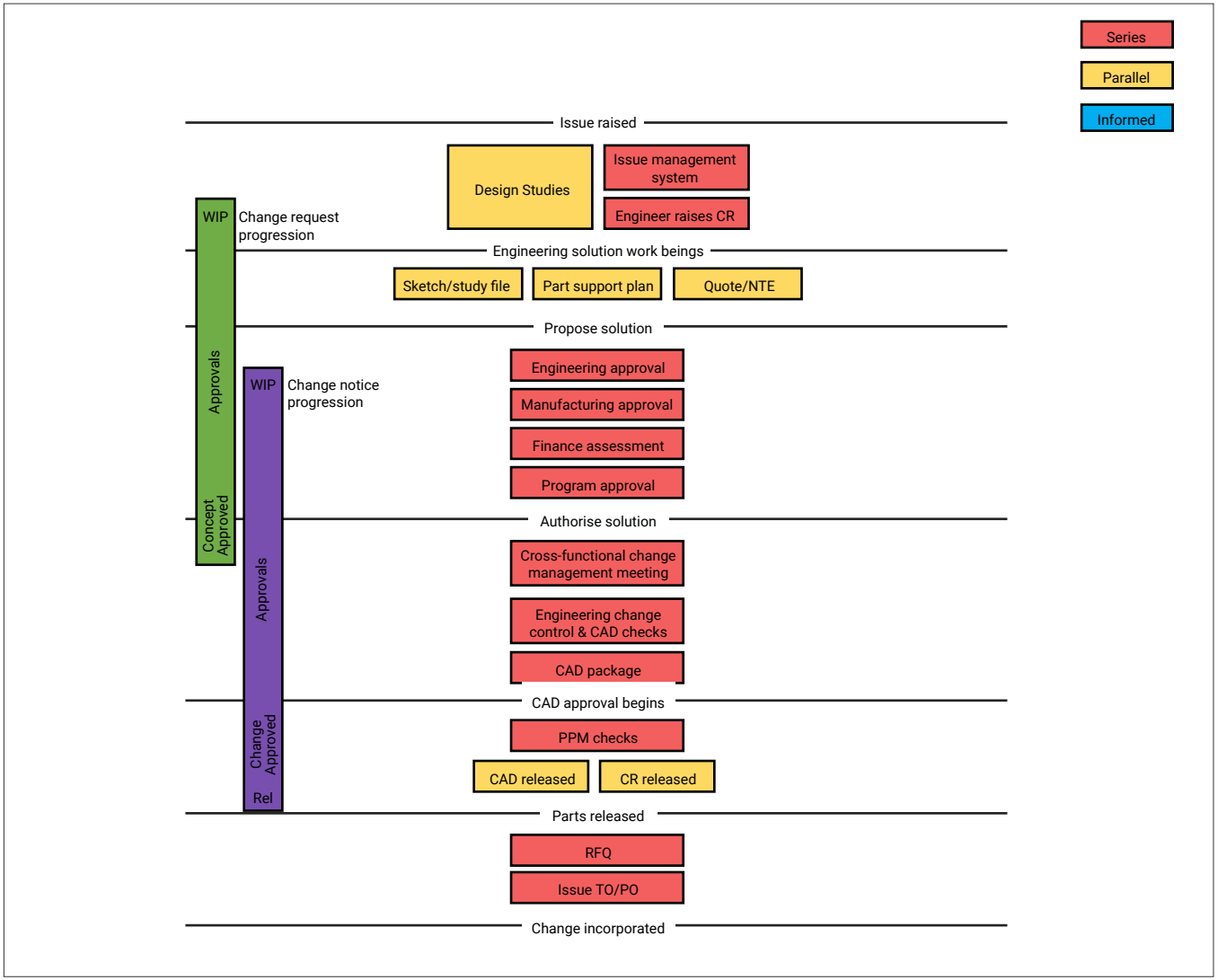
The electric vehicle manufacturer used an Excel-based DRS (Design Release System) which captured the release of parts and the issuing of revised part numbers.

The DRS captured little information about the change or which departments may be affected. Instead, the system addressed the Engineering and PDM/BOM administration, taking into consideration external designers.

The existing process focussed on how the systems worked, as opposed to how a process should work with a system mapped to that process.

INDUSTRY EXAMPLES

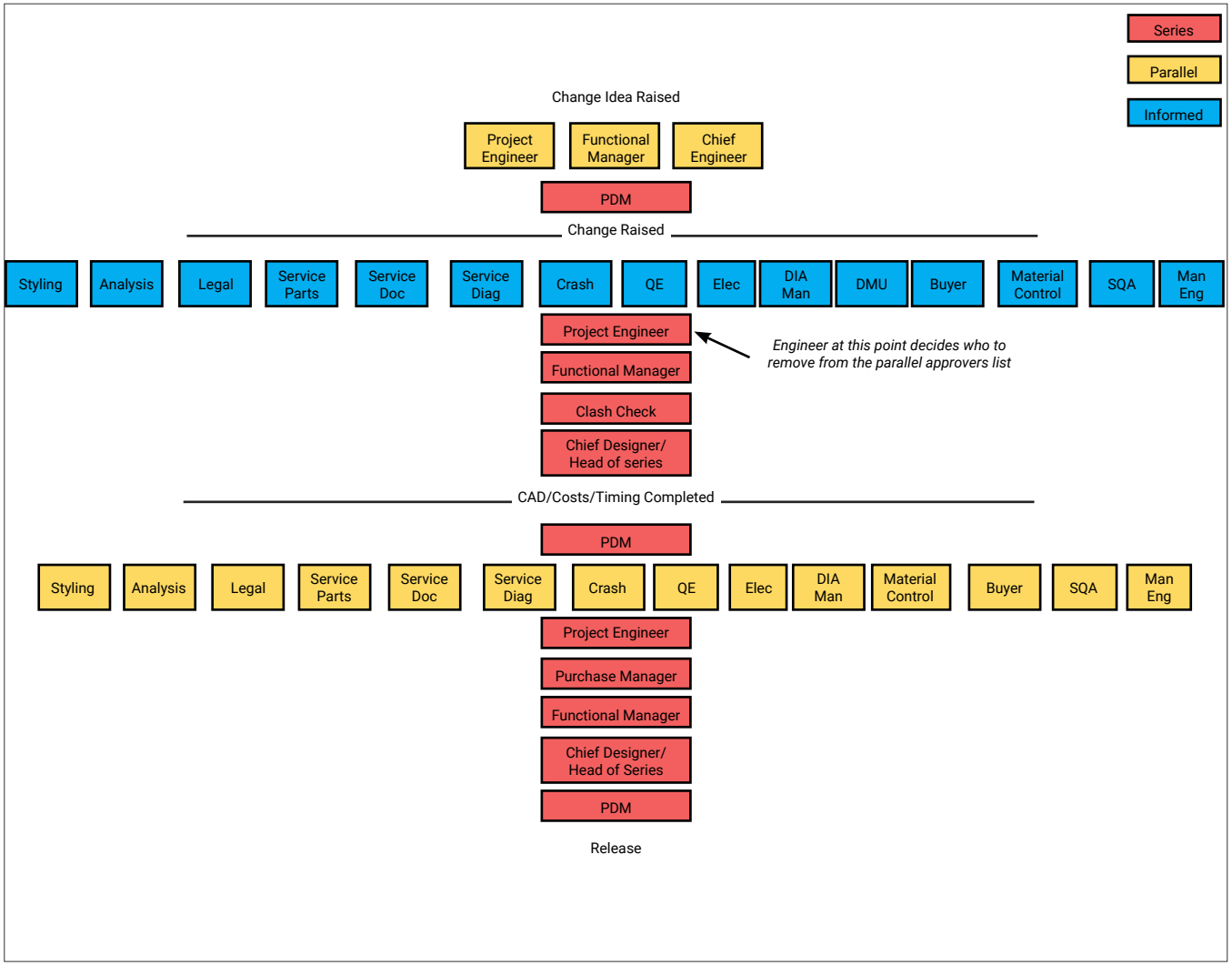
GLOBAL AUTOMOTIVE MANUFACTURER

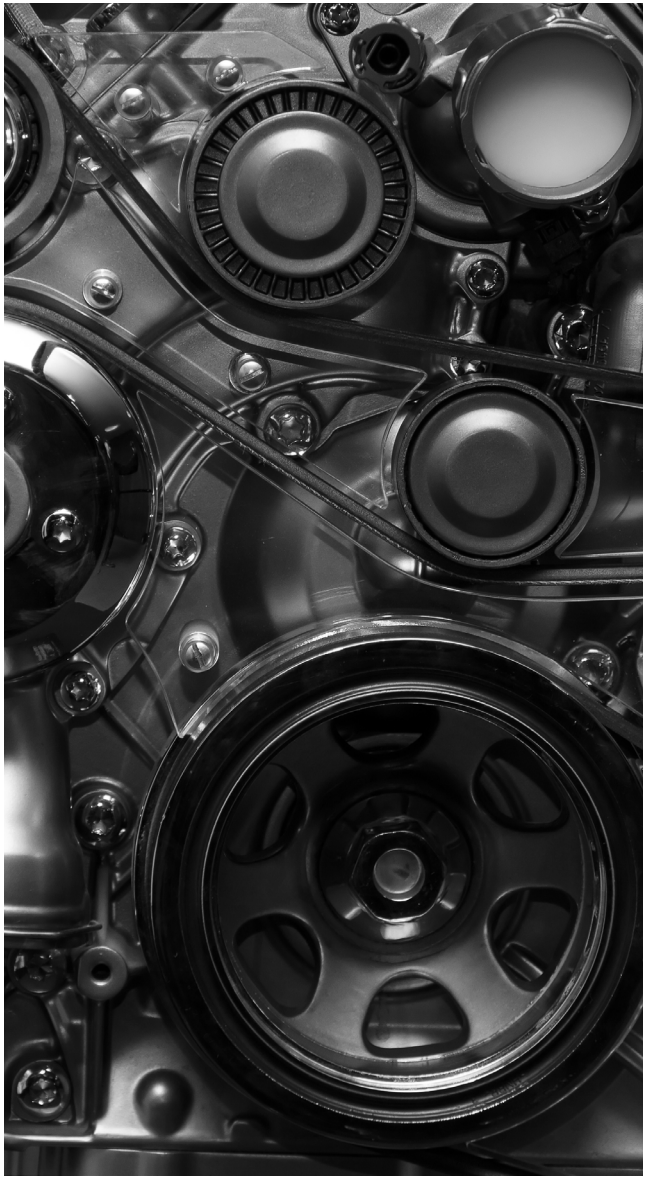


Extremely controlled through every stage, with multiple gates and cross-functional meetings needed for every change.

SPECIALIST AUTOMOTIVE MANUFACTURER

The engineer has ownership, deciding which departments need to approve changes, putting the onus on them to choose the departments required for approval. There are still multiple levels of approval needed for each change.





SPECIFIC AUTOMOTIVE MANUFACTURER

Multiple stages of approval are needed to certify the change, in principle, before work can pass through the additional stages of approval. It is common to have duplication of many approvals at different stages, thereby minimising the risk of errors.

DECISION CRITERIA FOR SELECTING AN ENGINEERING CHANGE MANAGEMENT PROCESS

The ECM process has been designed for the manufacturer to enable controlled release of changes, with flexibility for each stage of a programme and clarity for all stakeholders prioritised. The solution is based upon the Seven Core Principles of Change Management.

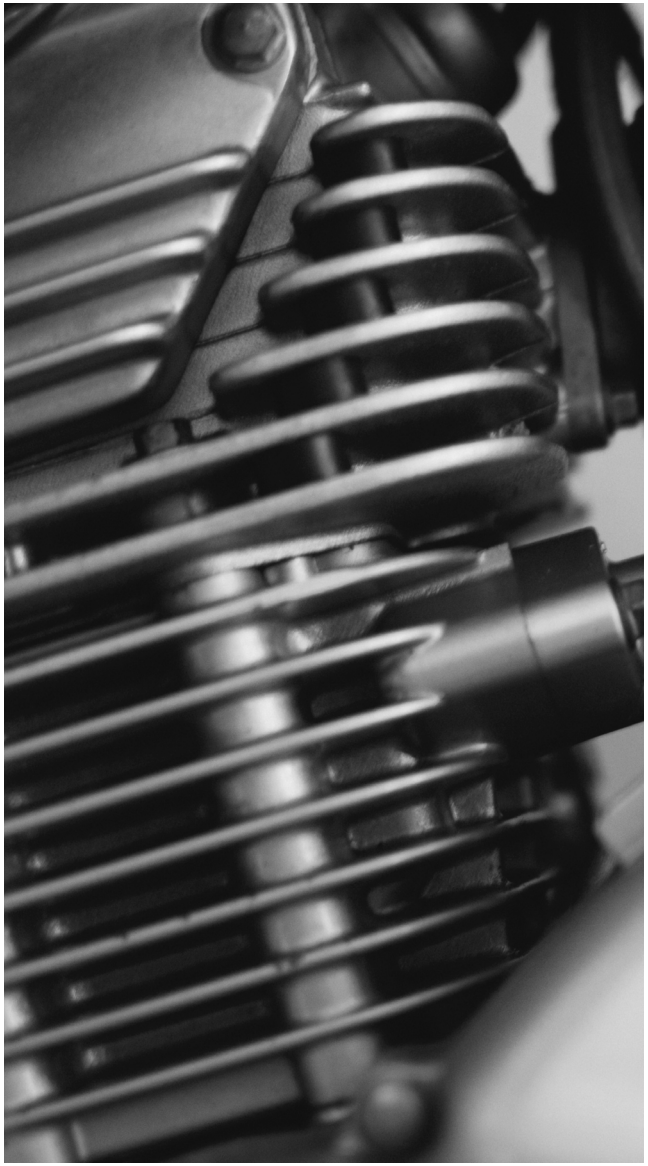
THE SEVEN CORE PRINCIPLES OF CHANGE MANAGEMENT

- **Approvers should…**
  - only approve the same data once
  - be based on the change content
  - be based on the programme maturity
  - be based on the programme thresholds
  - be timed appropriately
- **Single points of failure should not exist**
- **Teams should be trusted to do their job**
- **The process should be measured with meaningful KPIs**
- **Transparency, clarity and visibility should be upheld**
- **The right data should be available for the right people in the right format**
- **A system is not a process**

ECM THROUGH THE PROGRAMME LIFECYCLE

The process must be flexible enough to support the lifecycle of a programme through its various stages. During each stage, different areas of the business and design become more important, so these areas should be protected.

Program stage	Must protect	Sensitive to	Importance of
Concept	Product functionality & key attributes	Design & definition	Agility, flexibility & simplicity
Prototype	Prototype testing	Orders	Cost / weight
Launch	Product launch date	Testing	Timing / quality
Production	Production line uptime	Cost down / warranty	Robustness & traceability



THE ENGINEERING CHANGE MANAGEMENT PROCESS WE DECIDED ON

The process defined for the EV manufacturer was based upon The Seven Core Principles of Change Management. The process revolved around a flagged approval system rather than a staged approval system.

This method provided an opportunity for departments to review all change requests relevant to them, with the option to raise a flag to indicate that a change should not be made or requires attention.

The release would then proceed from the point the inputs were received. To address key safety and audit necessities, some departments were also marked as mandatory approvers, meaning they would need to give approval for the change to reach completion.

PROCESS SUMMARY BY CHANGE REQUEST STATUS

CREATION

An idea for a change is generated. This can come from multiple sources and for a variety of reasons. The relevant engineer will create a solution for the change; this will be captured within a Change Request.

This includes the need to create a new part (while the system should be set up to allow for all new parts to go through this process, a need has been identified for a bypass for new parts now, with the ability to bring in the full process for new parts in the future).

The Change Request will contain four main parts:

- **Design Change Summary**
  A sketch or CAD mock-up of the proposed design change
- **Key Attribute Change Summary**
  Estimated cost/timing impacts
- **Consideration of affected function groups**
  Indication of other engineers affected by this change
- **Change Priority**
  Changes that address safety, reliability or legislative issues must be clearly identified and linked to the appropriate entry in the issue management system

All affected function group engineers and function leaders will need to approve the change for it to process any further. This is to prevent wasted time from the rest of the business if the engineering solution is not yet agreed upon within the engineering teams. If extra funding is needed for external full-service supplier engineering, design and/or testing, it is also sourced at this point.

A category of change should be assigned. This will then define the urgency of the change and will set the number of days needed for the approver to review the change.

Here's an example:

1. CRITICAL *2.* MAJOR *3.* MEDIUM *4.* MINOR *5.* LOW

Detail of example categories:

Critical: Job Stopper, critical, legal or safety-related issue

Important: Critical and/or Health and Safety related issues must be immediately escalated to the next managerial level before raising the change request.

Major: An issue that will have significant implications on schedule, cost and/or quality.

Medium: An issue that will have some implications to schedule, cost and/or quality.

Minor: An issue that will have minor implications to schedule, cost and/or quality.

Low: Low importance issue/documentation only, with no effect on schedule, cost and/or quality.

The engineer has the responsibility to then set which departmental approval flags are mandatory. If the part needs to be approved by a safety-relevant department, the engineer should make sure the safety department is set as a mandatory approver. All other departmental approvals will then be considered optional.

CONCEPT APPROVAL

Once the Change Request has been raised and created, it should then be reviewed by all affected functional engineers and the functional leads. If any externally funded design work is also needed, authority for the work to be done should be sought.

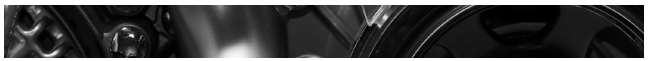
Once all affected function groups signal their approval, the concept of the change is then approved.

WIP (WORK IN PROGRESS)

Once the change concept is approved by all affected functional engineers and leads, it is open for monitoring and available for potential approval by all departments. Any reviewing department can change their approval flag from optional to mandatory if they think their department should be involved with the change. In order to avoid heavy-handed use, metrics showing the number of optional flags being changed to mandatory should be monitored.

Engineering can then start their CAD work and update the Bill of Materials (BOM). Once CAD work and drawings are complete, a Request for Quote (RFQ) can be submitted. A notification is then sent to approvers signifying that the CAD work is complete. This is followed by departments such as Clash Check, Safety and Homologation beginning their work and reviewing the change.

At this point, CAD must be locked to make sure a representative quote is received and departments reliant on CAD can carry out their work with a representative model and drawings. The CAD design should be approved by the functional lead and locked. If design changes are needed later, the engineering function manager must reset the approvals.



Once the formal quotation and support plan (timing) have been received, prices and lead times can be updated. Again, a notification is sent to approvers that the final quote has been received, then departments such as Programme and Purchasing can begin their work and review the change. If any of the thresholds are breached by the change, mandatory approval flags are imposed upon relevant departments.

REVIEW

Once all these inputs are complete, a set time limit is triggered for relevant departments to review and, if needed, approve the change. Mandatory approvers are also subject to this time limit. If the time limit expires with outstanding mandatory approvals, the change is not progressed further and is highlighted to senior programme management.

RELEASE & CLOSE

Once mandatory approvers have validated the change and the time limit elapsed (or all approvals are complete), the change is then considered approved and can be released. This allows for final CAD to be sent to suppliers, POs and TOs to be signed and the change to be implemented. Once implementation is complete the Change Request is closed.

APPROVALS

Upon approval from appropriate Functional Leads for a particular engineering change, a list of further departmental approvers is triggered and opened.

A time limit for an approval response in the system would then be applied. This starts from when the engineering inputs (frozen CAD/Cost/Timing) have been received:

- **Green Flag to confirm review and acceptance of the change**
- **Amber Flag to indicate management attention is needed**
- **Red Flag to stop the change request. Supporting evidence would need to be presented to the Chief Engineer and program showing why a stop has been applied to the particular change**

Re-approval from a departmental group will only be needed if a quote from a supplier has come in with significant variation from the estimation provided on the Change Request, as defined by predefined thresholds, or additional design change has been necessary before release.

The approval list should consider the following:

- **Purchase**
- **Manufacturing**
- **Program Team**
- **Quality**
- **SQA**
- **DMU/DPA team**
- **Safety**
- **Service**
- **Homologation**
- **Cost Estimating**
- **Chief Engineer**

The Engineer creating the Change Request will allocate the mandatory approvers for the change. Departments not listed as mandatory will, by default, be set to optional.

This will be reflected in the dashboard, making it easier for approvers to prioritise changes for approval. The consideration of thresholds may also determine what level of authority is needed to approve the change.

EXAMPLE APPROVAL DASHBOARD

Key	
	Red Flag - Release on Hold
	Yellow Flag - Management Attention Required
	Green Flag - Approved
	Mandatory Approval - No Response
	Optional Approval - No Response

Details					Inputs				Approvals											
Change	Description	Engineer	Aging	Days Till Release	Concept Package	CAD	Cost	Timing	Purchase	Man Eng	Program	Quality	SQA	DMU	Safety	Service	Homologation	PCE	CE
16233	Initial Release of Bumper		5	0	Link														
19840	Bracket Change		7	0	Link														
11920	Grease for BSR issue		6	1	Link														
16940	Craftmanship updates		5	1	Link														
17322	Product Change		3	2	Link														
17195	Material Change		2	5	Link														
15852	Change profile of flange		4	-	Link														
14575	Initial Release of Panels		3	-	Link														
12152	BoM Correction		2	-	Link														
16903	Initial Release of CHIMSL		2	-	Link														
16646	Change tolerances		1	-	Link														
19161	CAD Correction		0	-	Link														
17864	Air vents updates		0	-	Link														
10630	Door stiffening		0	-	Link														

SCENARIO 1

Causal factors could be used to define a pre-determined list of function group approvers assigned to the change, within the change request dashboard.

Example A: Cost only, would include Purchase, Program Team, Cost Estimating and Chief Engineer. All other function groups would be redundant in this scenario.

Example B: Design Change, would include all function groups listed above as all would be affected.

SCENARIO 2

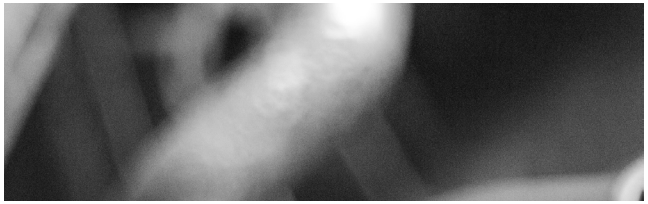
Using scenario 1 as the basis but include all functional approvers, with the idea to apply a "work queue" to prioritise approvals needed dependent on the type of change request raised.

Example C: A CAD-only change would appear as low priority in the purchase approval work queue, but high for the DMU/ DPA team and SQA.

SCENARIO 3

The engineer can determine the list of approvers depending on the type of change request raised.

Safety needs to be recognised as an important approval from a business, ISO and legal perspective.



APPLICATION TO PROGRAM STAGE

The approval process would apply to the following program stages:

- **Prototype**
- **Launch**
- **Production**

For Concept approvals, the need for non-engineering departmental approvals would be redundant, as the design would not be mature enough at this particular stage.

DOCUMENT: DESIGN CHANGE SUMMARY

The principle of the Lite-Design Change Summary form is to capture the technical engineering detail for a change in as lightweight a form as possible.

The purpose is to create a document of any change to be approved by the engineering stakeholders and reviewed by other stakeholders before CAD and BOM work is completed for a change.

Useful points to contain in the presentation:

- **Part Numbers**
- **3D Model (ideally before/after change)**
- **Design Notes**
- **Manufacturing changes**
- **Studies or Functional tests that have been carried out**
- **Related issue numbers or details of why change is required**
- **Document should allow Engineering teams to approve change feasibility and begin triggered workflows of CAD work and BOM work**

JUSTIFICATION & EVIDENCE FOR THE NEW PROCESS

The ability of the process to include or exclude functional areas of the business depending on the stage of the programme means that the process is flexible for programme maturity. But approval is still needed for any change to a part.

Having thresholds for mandatory approvals gives approvers the ability to manage the workflow of approvals in a pre-determined way, identifying which changes may have a greater impact on the programme than others.

Unless there is a threshold exception or resubmission, approvers will only need to approve a change once. Not mapping the process to a specific system - and leaving the process as system-agnostic - means the process has been mapped to the business needs and not a specific system. This provides flexibility to map an ECM system to the process, not the other way around.

As a change is progressed through the process, its progress and state can be captured, allowing for the change to be measured. This allows the entire process to be measured and KPIs and dashboards to be created.

Opening the dashboard early in the change gives transparency, clarity and visibility to the business of upcoming changes.

RISKS OF THE NEW PROCESS

A major benefit to this process is empowering engineering teams to carry out the design work required, as it gives them the ability to choose which functional areas of the business should be mandatory approvers.

This adds a level of risk, that a functional area is missed from being a mandatory approver that may be needed. Because of this, unless the functional area picks up on the change via a dashboard overview, the change may be accepted and approved without the functional area's input.

This risk is mitigated by the engineering functional leaders assessing the change before the concept of the change is approved; allowing the optional/mandatory approvers to be assessed.

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ABOUT QUICK RELEASE_

Quick Release_ is the leading Product Lifecycle Management consultancy. QR_ has 350+ professionals across three continents working alongside some of the largest, most innovative and prestigious vehicle manufacturers, aerospace technologists and Tier 1 suppliers.

Our mission is to enhance competitive advantage by bringing products to market faster and more efficiently. We do this by improving product data quality and flow through every part of a business from concept to manufacture, working with senior management teams to tackle the biggest blockers of productivity; we release engineers to focus on the product, not the data.

Leveraging bespoke tools, methodologies and benchmarking, our professionals offer the full spectrum of PLM services designed to guide start-ups through the unknown unknowns, take businesses looking to scale to the next level, and facilitate transformation in established manufacturing and technology OEMs. Read more: Why does PDM matter?

ALL CLEAR ON CHANGE MANAGEMENT?

If you'd like to know more about engineering change management, or any other aspect of PLM, we'd love to hear from you.

QR_ have advised on and implemented engineering change management for EV start-ups, specialist, volume, and commercial vehicle manufacturers.

Our SMEs would love to hear your change management headaches and explore quick, unobtrusive solutions that deliver lasting, whole-business value.

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