Optimised Lean, Green, Production Lines

The automotive industry invented Lean manufacturing, and with the advent of technologies for digital and green manufacturing, supply chain integration and transparency, and more widespread automation of the manufacturing process, automotive continues to be a vanguard of clean and heavily optimised product value streams.

But the changing technological and regulatory environment which has enabled many of these changes, brings risks as well as opportunities. Lean manufacturing is heavily optimised, and with capital-intensive production lines, a climate of change can make longer-term investment decisions highly unpredictable in their outcomes.

Brexit and the Covid-19 pandemic have made automotive manufacturers all too aware of the risks associated with unstable resource inputs to their production capacity. Heavily optimised Lean production lines can be greatly disrupted by the slightest interruption to the flow of value. But even as the world – hopefully – approaches a new normal following the worst disruption of these turbulent events, the automotive industry can't entirely relax about the stability of its inputs over the coming decade.

Pressure to innovate in the automotive industry has perhaps never been stronger in its entire history than it is right now. When Agile was developed by the software development industry around the turn of the millennium, it was because the industry had discovered that traditional engineering management approaches could no longer produce a rapid enough time-to-market to serve the pace of innovation; by the time a product was rolled out, technology had improved so much that it was already obsolete.

Agile itself can never be adapted comfortably to industries with complex supply chains, extensive regulatory requirements, high product integration costs and both human and physical capital needs that differ so radically between design and fabrication. But the unstable requirements and rapidly changing customer demands associated with a climate of innovation will put just as much pressure on the automotive industry of the '20s as it did the software industry of the '90s.

Heavily optimised Lean manufacturing requires stable inputs to remain effective, not just in terms of resources but also in terms of knowledge and engineering objectives. Adapting to a technical environment where that stability is much harder to obtain will require a transformation as dramatic as Agile to the engineering practices of the automotive industry, to enable it to engineer for Lean – provide engineering stability, in other words – in a climate of innovation.

Many in the automotive industry are already looking to systems engineering as a way to adapt to this challenge. Developed by the defence industry and in continuous, evolving use since World War II, the systems engineering process has a long-proven track record of reducing risk in contexts where reliability and performance are a matter of life and death.

Systems Engineering (SE) techniques are fundamentally about finding ways to analyse, model and plan the behaviour of a system as a whole and in its context, above and beyond the details of individual components. By having a suite of processes and tools designed to model and anticipate the *structure* of a system, projects can have assurance from the start that the right thing is being built in the right way, and that the project will interact appropriately with its context. This drives down cost by reducing the risk of mistakes and unanticipated defects, while simultaneously driving up quality by tying engineering activity more closely to precisely defined stakeholder needs.

In the context of Lean manufacturing and fast-paced innovation, systems engineering can provide the clarity and foresight necessary to minimise the risk of project objectives changing in the course of development. By modelling and planning the product as a system, it is possible to anticipate many such issues much earlier in the development process and, critically, prior to mapping the value stream and to generating significant sunk costs.

And when change does come out of the blue, systems engineering methods produce adaptable models and plans which enable engineers to much more straightforwardly assess the impact of those changes on the system as a whole.

Stable Requirements

According to the Project Management Institute's global 2020 'Pulse of the Profession' study, Project Managers (PMs) in the manufacturing industry report poor upfront planning as the primary cause of project failure[1]. In the same study, manufacturing PMs reported that 40% of project budgets are lost in a case of project failure. In all, the survey reported that 13.5% of total project and programme spending in the manufacturing industry was wasted due to poor project performance; *more than any other industry*.

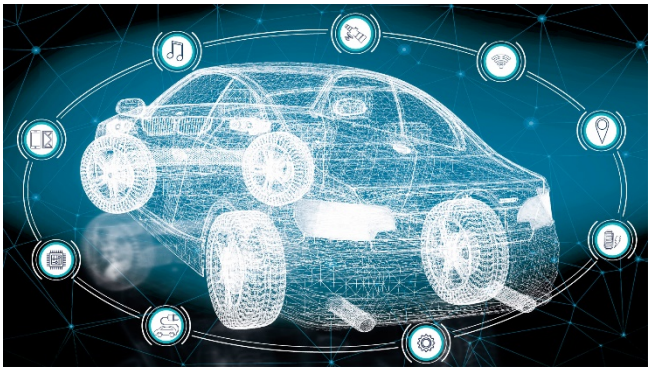
SE can address these challenges by taking a robust and scientific approach to requirements management that cleanly and specifically identifies ambiguities and gaps in stated stakeholder needs. The best way to get a straight answer is to ask a straight question, and the SE process is very good at generating straight questions, and requires you to ask them of as broad a range of stakeholders as possible.

SE treats the requirements engineering process like formulating a scientific hypothesis. The philosopher of science Karl Popper famously said that for a statement to be considered scientific, it must be falsifiable; you have to be able to tell the difference between a world in which the statement is true and a world in which it is false. Similarly, systems engineers work towards requirements by which it is possible to tell the difference between a system that achieves them and one that does not.

The requirements that result are – among other benefits – clear, verifiable, functional, minimal and consistent. The SE process guides you to as complete a description of the product as possible at the earliest stages of design, and when change does happen at a later stage, gives you a robust and speedy way to fully understand the implications and adapt.

Adaptable Models

An SE approach to requirements keeps focus on the functional description of the asset, the 'use case'; a problem that needs to be solved, or an opportunity to be pursued. The context and environment for the system – its basic inputs and outputs – should be understood as clearly as possible while the system as a whole is still being treated as a black box. In a systems engineering process, only then do engineers start to formally investigate the sorts of systems which could solve the stakeholders' problem.



1 PMI (2020). Research Highlights by Industry and Region 2020.

As well as the direct benefits of specifying project objectives with such a high degree of precision, this approach to requirements also enables systems engineers to construct sophisticated models of products which can anticipate many potential problems before committing to development costs.

These models touch on every aspect of the life cycle and are designed to predict the behaviour of a system taken as a whole.

A formal SE model is built out of black boxes, taking inputs from users and the environment and outputting stakeholder needs. Until the finest levels of detail are reached, the model is not concerned with how individual components work, but rather with the structure of a system as a whole; the inputs, outputs and interactions of system elements. It's about recognising that the structure of a system, rather than the specifications of individual parts, are what determines its behaviour as a whole.

As such, the models are nearly always built from the top down, with the system as a whole taking inputs from users and the environment, and outputting stakeholder needs. As requirements get clarified and detailed, the model progresses down equivalent layers of complexity, at each stage fundamentally treating subsystems and individual elements as black boxes that transform inputs into outputs.

Therefore, the benefits of an SE model are not just confined to presenting a clear, coherent architecture to designers, testers and operators, it also allows the behaviour of the system as a whole to be anticipated prior to proceeding with development, and potential defects to be anticipated and addressed before mapping the manufacturing value stream.

SE models, in other words, provide much more stable engineering and knowledge inputs to the development process, allowing Lean practices to optimise the manufacturing workflow much more narrowly.

A Single Source of Truth

SE is also notable for taking a whole-life cycle view of the product, providing engineering governance processes for everything from business and mission analysis through to maintenance and disposal. As such, SE tools are designed to provide a single source of truth about a project, with an integrated and adaptable repository of project information serving requirements, design, workflow management and quality activities.

All teams involved in making and maintaining the product at every stage of its life cycle can participate in that shared project definition, both inside your organisation and when you have to collaborate with suppliers.

If SE processes are followed and SE-specific tools are utilised, that information is retained in a modular way, with requirements, designs and workflows for individual components easily separable from the project as a whole. Information is retained, and its value maximised, not just within a single project, but from one project to the next.

For the Lean automotive manufacturer, SE tools, and the single source of truth they maintain, can provide a vehicle for process and product standardisation readily adapted to value stream mapping, Six Sigma standards of quality, and compliance with Advanced Product Quality Planning (APQP) processes. This stability persists not just throughout the product life cycle, but between one project and the next.

The best way engineering can support the Lean manufacturing process is by keeping inputs stable and predictable, such that manufacturing processes can be more fully optimised to the precise demands of a particular product. In an age of automotive innovation, SE processes and tools could be the best way for manufacturers and suppliers to secure that stability in a climate of rapid change.

If you have found this article useful, and would like to hear more about how your organisation may use systems engineering to better accelerate time to market, manage risk and improve quality visit: www.synthesys-technologies.co.uk or contact us on: cet@synthesys.co.uk

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