LEAN Development

Toyota is feted for its lean manufacturing, but before the production line beckons there is, what **Freddy Ballé** and **Michael Ballé** describe as, lean development.

Toyota Motor Company's production system, or "lean manufacturing" as it is known, has been extensively studied since the mid-1980s. Many companies are now working at adopting "lean" practices on their shop floors. But, production is only half the manufacturing problem. Toyota's product development process is just as innovative and counter-intuitive to traditional engineering management as lean manufacturing is to mass production. According to a National Center for Manufacturing Sciences report, Toyota product development projects can take half the time of US equivalents, with four times their productivity (150 product engineers utilised by Toyota per car programme versus 600 for twice as long at Chrysler).

As in the early days of the Toyota Production System (TSP), various approaches and best practices are vigorously debated in the automotive industry. From our experience with various suppliers to Toyota, interviews with Toyota engineers and the seminal research of Durward Sobek II and James Morgan comparing Toyota's development process to its US competitors, we have tried to piece together current knowledge of Toyota's lean practices.

In this sense, Toyota's approach to product development can be labelled *lean development*. Its starting point is Toyota's ability to make sure that its engineers actually care about what customers think of their product. This means both creating a strong vision for the future product and communicating this vision to everyone involved in the development process. Once expressed clearly, this early vision serves as a reference to arbitrate conflicting constraints within the design process. In some cases, this vision can fundamentally challenge the existing product.

The second key to the Toyota development process is that it limits late engineering changes. While car makers are painfully aware of the disruptive power of late engineering changes, few have learned to limit them. Toyota has perfected a process which mostly avoids such late changes. Indeed, the Camry project manager at the Toyota Technical Center in Plymouth, Michigan, claims that the car's chief engineer, Mr. Yamada, pushed for what he called "perfect drawings", or "Zero EC" in Toyota-speak: no engineering changes were allowed after production drawings were released.

The third recurrent issue is mastering the flow of drawings and tool elaboration. The aim of any design process is to "industrialise" drawing production to increase overall design effectiveness. This is rarely possible because of the on-going changes which cross-impact throughout the development process. Having largely solved key issues upfront in its design process, Toyota focuses on precise, tightly scheduled production of the actual drawings. In the Camry's case, the number of vehicle prototypes was cut by 65 per cent, and the number of crash tests halved by the use of digital assembly software.

This links to the final key to an efficient development process: focusing on quality and cost in production itself. Drawing on its expertise in lean manufacturing, Toyota examines all aspects of the car's production to make sure that it will be built within the targeted cost brackets once the design is released. Toyota's emphasis on lean production and waste reduction starts at source.

These four key factors are the aim of every development process. What does Toyota do to succeed in practice where others fail?

It's a system thing

As with implementing the Toyota production system, a more precise understanding of development practices doesn't necessarily help to improve the efficiency of engineering projects for a number of reasons. First, it is not a collection of best practices which can be implemented piecemeal, but a system. Furthermore, a clearer understanding of the system also shines a different light on the practices themselves, and, in many cases, changes their intended *purpose*. As such, many of the Toyota practices only make sense in the light of the overall system. Shigeo Shingo, one of the early contributors to the TPS used to say that when asked "What is the Toyota Production System?", eighty per cent of people would say "It's a kanban system", another fifteen would know enough of its working in the factory to say "It's a production system," and only five per cent would really understand its purpose and answer: "It's a system for the absolute elimination of waste".

The same can probably be said about Toyota's product development process by replacing "kanban" with "concurrent engineering" which is probably the most well-known (and misinterpreted) design practice in the system.

Second, most approaches to product development improvement tend to focus on improving the product development process, proposing a variety of organisational fixes ranging from full re-engineering to local continuous improvement efforts. However, the design process is a proximal cause of

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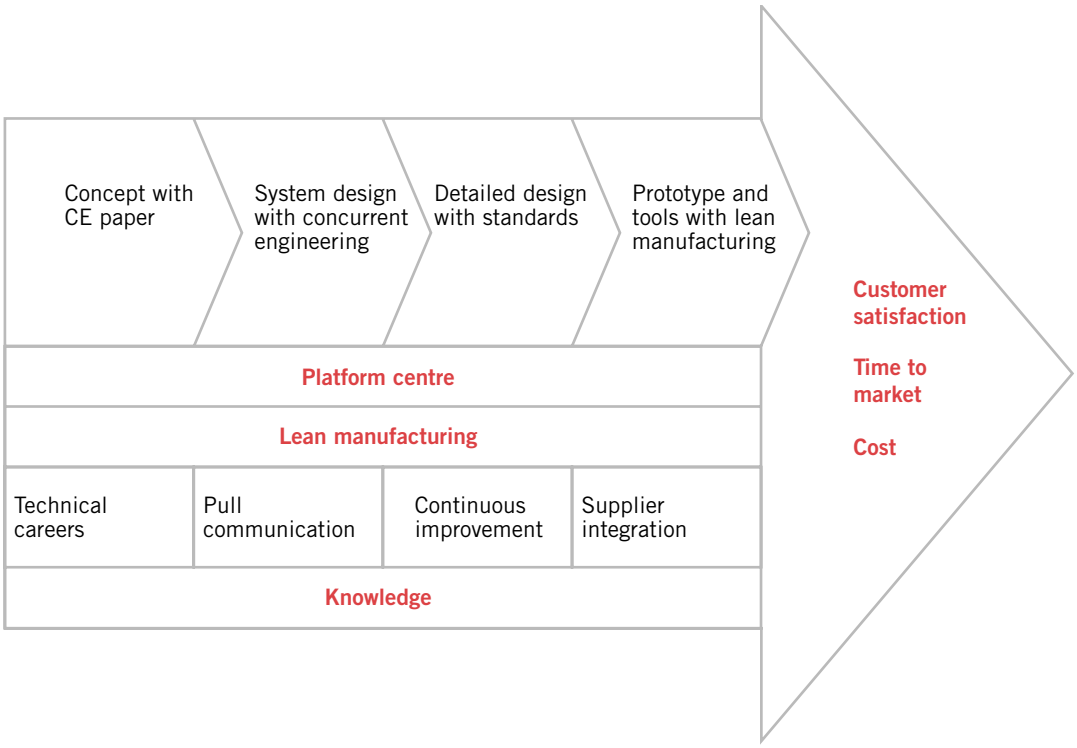

Figure 1.

performance, not an ultimate one. Toyota's current development process is the result of the interaction between a set of practices and situational market conditions. To understand Toyota's lean development process, it is necessary to identify the underlying core practices and attitudes.

Any of the practices, worthwhile as they may be, taken out of the system will not yield significant efficiency gains in the development process. The system has to be visualised as a whole in order to understand each of its parts – see Figure 1.

Toyota's product development process has four phases:

- A concept phase leading to the chief engineer's (CE) concept paper
- A system-designed phase with concurrent engineering
- A detailed design phase with design standards
- A prototype and tooling phase with lean manufacturing.

Chief engineer concept paper

In their 1991 study of the relationship between organisational structure and project performance, Clark and Fujimoto introduced the notion of "heavy-weight project manager", a practice which has its roots in Toyota in the 1950s. According to Fujimoto, an ideal product manager has the following roles:

- Coordinating broadly, not just in engineering but also production and sales
- Coordinating the entire project from concept to market
- Concept creation and concept championing
- Specification, cost target, layout and major component choices, making sure that product concept is accurately translated into technical details of the vehicle
- Communicating directly and frequently with designers and engineers
- Establishing direct contact with customers (the product manager's office conducts its own market research besides the regular market surveys done by marketing).

This requires a special mix of skills. The ideal project manager is multilingual and multi-disciplined; more than a neutral referee or passive conflict manager but willing to initiate conflict in order to prevent product designs from deviating from the original product concept; possesses market imagination, or the ability to forecast future customer expectations based on ambiguous and equivocal clues in the present market; walks around and advocates the product concept, rather than doing paperwork and conducting formal meetings; and is principally an engineer by training with broad, if not deep, knowledge of total vehicle engineering and process engineering.

The chief engineer at Toyota is first and foremost a technical expert who has a large input in the car's architecture. Although he is responsible for the project from concept to market, he has little formal authority in the matrix, but is mostly recognised →

→ by his experience, his technical and communication skills. He has a very small dedicated team of experienced product engineers as well as manufacturing engineers – but all his other resources are in the functional organisation. He summarises his vision for the car in a "concept paper" which leads into the system design phase.

System design with set-based concurrent engineering

Concurrent engineering has been seen as a source of development performance ever since it was highlighted by Clark and Fujimoto in their 1991 study. However, most companies interpreted this as the need to have more frequent feedback loops between engineering and production. In many cases this led to disappointing results as the amount of rework increased rapidly while at the same time people were trying to reduce deadlines for milestones.

Toyota seeks to identify all possible problems and to resolve them early in the process. By nature, it's a messy process, given to ambiguity and negotiation. Ultimately, conflicts tend to be resolved by returning to customer satisfaction criteria. As design progresses the sets of solutions gradually narrow according to the information received from stakeholders. As the design converges, engineers commit to staying within the set so that their colleagues working in parallel can rely on their communication. Consequently, although Toyota considers a broader range of possible designs than most other car makers and actually delays firm decisions, by progressively reducing specifications and resolving ambiguity it considerably shortens its development cycle. During the critical period of the system design phase, product engineering, manufacturing engineering, purchasing, and quality have correspondents located in the *obeya* (big room) under the CE's leadership, to develop a team atmosphere with one experienced engineer from each division. After this period, they meet at least every two weeks.

Repeated attempts by western car makers at encouraging concurrent engineering have failed. Designers are often blamed for their apparent lack of concern for manufacturing issues. In reality, during concurrent engineering efforts to get functions to discuss the car concept upstream, manufacturing engineering tends to expect drawings to be able to voice its opinion of the design – something of a catch-22. In Toyota's set-based concurrent engineering approach, manufacturing engineers produce detailed check-lists of what they can, or cannot do, which define the design space in a non-restricting way. Each parameter is obviously opened to debate, but ultimately, this gives designers a loose framework to operate with and the checklists serve as a concrete basis for communication between designers and production engineers.

Detailed design with standards

In the second part of the development process, Toyota reduces variability by relying strongly on the standardisation of skills, processes, and design themselves. This high level of standardisation is key to eliminating rework and waste, and paradoxically again, opens the way for capacity flexibility. In the development process Toyota uses a number of standardisation tools, such as checklists; standardised process sheets; and common construction sections.

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Although the number of checklists can become overwhelming, this detailed standardisation of the design process is critical in maximising learning and continuous improvement in the design process, as well as speeding it up while maintaining its reliability. As major problems are resolved and solutions sets are refined, the *obeya* ends and meetings occur less frequently, moving the process towards more formal communication.

Prototype and tools with lean manufacturing

In general, Toyota develops two series of prototypes, which are not used to test solutions, but to choose the different sub-systems and check their integration. The first products of the first wave (1S) are very carefully assembled in a slow build to check all interfaces. All others are assembled using lean manufacturing techniques. Simultaneously with the 1S fast build, manufacturing engineering conducts its own slow build to identify manufacturing and assembly issues. Prototyping is a time of intensive work for body engineers, particularly at the first slow builds which is a privileged learning time for junior engineers in body engineering and manufacturing engineering. This is the last stage at which engineering changes will be accepted. They work with system engineers, prototype specialists, quality assurance experts and production assembly team leaders and are expected to respond very quickly, signing off sketches or drawings within 48 hours if not on the spot.

Overall, Toyota's lean development process can be characterised by two different stages: a first,

front-loaded, "noisy" exploratory stage where the overall concept for the vehicle emerges and many alternatives are explored; and a second "detailed planning" stage where drawings are realised with the objective of attaining "zero EC": no engineering changes once the drawings are released, and then using lean manufacturing techniques to build both prototypes and tools. Toyota has sometimes been portrayed as making more mock-ups than its competitors. In practice, all car makers develop roughly the same number of mock-ups to choose from. Toyota's uniqueness lies in its detailed discussion of manufacturing issues at the mock-up stage, whereas its competitors are mostly concerned with style and engineering. Toyota is willing to invest time and effort in learning early on in order to make sure that the end solution is truly the best.

This early "open" phase then narrows down rapidly to a very tightly planned detailed drawing phase which then operates according to lean manufacturing principles.

Platform centres

Yet, Toyota is perplexing. While its product development process is unusually efficient, the firm does not use many of the recommended techniques for process effectiveness. Its development teams are not co-located and engineers (with the exception of the chief engineer and his small staff) are not dedicated to one programme. In fact, cross-functional rotation is unlikely for the first ten years of an engineer's career. By all accounts, Toyota appears to be a rather stodgy, rather conservative company with strong functional silos. Yet, it manages to systematically outperform its competitors. What kind of organisation can then sustain its unique product development process?

Originally, Toyota was a functional organisation and its development programmes were organised around a heavyweight project manager who managed somehow, through authority and charisma, to make the functions responsive to his own project's needs. However, as the firm grew this simple organisational model progressively became unsustainable. In 1991, a chief engineer had to coordinate people in 48 departments in 12 divisions to launch a new product programme. Furthermore there were too many projects for each functional manager to manage the engineering details of each, as well as coordinate across projects, and, conversely, more junior chief engineers found it harder to fight the authority of functional managers and were no longer such heavyweight project managers. As a result, in the early 1990s, Toyota fundamentally reorganised its product development organisation and moved towards platform centres, with four distinct development centres organised to develop product families.

Each centre has a general manager in charge of the functional managers, the chief engineers and its own planning division. In practice, each development centre has an incentive to minimise its costs by transferring resources and components between projects. Each centre also defines its own vision for product development. This organisation evolved over time and there is now a further centre devoted to the Lexus platform.

In many ways, the platform organisation is key to the performance of a lean product development process. It encourages coordination within projects; helps optimise human resources utilisation, particularly in the precise scheduling for the detailed design phase; and it encourages product standardisation by the exchange and re-use of components across a platform.

Lean practices

Organisation alone cannot explain the success of Toyota's product development process. Several of its competitors have tried similar organisational designs with disputed results. Platform centres may encourage certain behaviours but can hardly be the ultimate explanation. We believe that, underlying the organisational structure, one should not lose track of how deeply imbedded lean manufacturing is in Toyota's DNA.

The influence of Toyota's lean approach to manufacturing can be felt in every aspect of its product development process. Toyota engineers follow a number of practices which would not appear in any organisational charts, but which are essential. Many of these practices reflect the core principles of the Toyota Production System. For instance, the "*genchi genbutsu*" principle of "go and see for yourself" can be found throughout the design process – in the early concept phases, the core team around the chief engineer is supposed to tour plants and dealerships to have a hands on understanding of the car they're trying to imagine. At the prototype build stage, the core team meets at the end of every day to discuss the progress of the build. →

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→ It is notable that Toyota does not seem to follow any of the fashionable trends in the industry, such as team co-location, design automation, six sigma initiatives, re-engineering programmes, and so forth. Instead, there is a commitment to knowledge creation. First, the technical career path of the engineers encourages the development of specific expertise. The first assignment of a young engineer is an improvement project. Second, the emphasis on "pull communication" supports the exchange of information among functional specialists. Continuous improvement through *hansei*, obviously constantly challenges status quo and opens the way for new knowledge creation. Finally, Toyota's collaborative work with it's suppliers is another source of practical innovation.

It would be tempting to assume that the key to Toyota's product development remarkable speed and productivity lies in its design process. Certainly, many of the Toyota techniques make sense on their own and would be beneficial anywhere. But taken separately, they are unlikely to deliver the kind of benefits people would expect.

"For TPS to work effectively," says Gary Convis, president of Toyota Motor Manufacturing in Kentucky, "it needs to be adopted in its entirety, not piecemeal. Each element of TPS will only fully blossom if grown in an environment that contains and nourishes the philosophies and managerial practices needed to support it."

The odds are that applying lean best practices will not deliver the wished for results unless managers question themselves seriously on their tacit approaches to knowledge creation. If you have the right experts, if they communicate effectively and they are given challenging goals, not surprisingly, they will deliver splendid products. Yet, for each new managerial initiative, organisational change or simple on the spot decision, managers can ask themselves these simple questions: Are we developing better engineers?; Are we helping them to share their knowledge across functions?, Are we giving them the proper challenges? If the answers are uncertain, it is probably their attitude they need to challenge before they even start looking at their processes. ■

Resources

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