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An integrated decision making framework for automotive product development with the supply chain

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Abstract

It is evidenced that manufacturing firms in order to be more competitive in market, must continuously update their product offers in order to better satisfy the customers' requirements. Management should use the supply chain features more frequently, as the increased rate of product introductions, demands more from a business and needs more efforts to deliver the new products effectively and efficiently. To deliver the products at the targeted cost, time, and quality, the supply chain must be aligned with New Product Development (NPD) decisions. This will allow the manufacturing firm to overcome problems such as (partially) failed product launches due to the lack of product availability because of insufficient capacities. The integrated NPD-Supply Chain Management (SCM) enterprise has the benefit of increased supply chain capability, thus increasing the effectiveness of new product introductions and improves enterprise's performance. This research mainly focuses on automotive sector due to its supply chain environment being the subject of extensive research within its product development integration. The research also introduces the development of a framework that integrates flow of activities within the manufacturing enterprises and shows that this contributes all the business functions. It also aims to focus on using current modelling tools to represent the product development processes of its Original Equipment Manufacturer (OEM) and its suppliers. Through this research, the aim is to link the product development (PD) within a SCM context for an extended enterprise and to investigate the effect of the integration of SCM with NPD. The possible integration points will provide baseline guidelines to identify the key decision making points within the entire supply chain.

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1. Introduction

NPD and SCM are the main areas of analysis within this research. NPD gives an opportunity of transforming a market requirement about product technology into a marketable product [1]. Along with tools from project management and concurrent engineering, different tools have been used to assess and integrate customer needs into product design.

There is lack of research that relates SCM and NPD to each other, for the product to be designed with the help of NPD tools and distributing the product with help of supply chain features. Only through SCM, it is possible to design, organise, and execute all the activities from planning to distribution within the value chain. SCM benefits by helping to organise and use more productively the network of suppliers, manufacturers and distributors [2]. The literature suggests that

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most SCM models and methods assume that product design decisions have been already taken [3].

But recently, it has been observed that there is a demand arising for the coordination of SCM and NPD. The approach called "design for supply chain management" [4] suggests that the NPD-oriented way of business can identify the supply chain constraints at the early stages of product development. All the support models of the NPD-oriented approach either consider bill-of-materials (BOM) or product architectures. Looking at existing tools available the researchers use product architecture-based models more frequently than others. It is "the scheme by which the function of the product is allocated to physical components" [5]. It has been argued that the product architecture, rather than BOM, will help in addressing more effectively like the trade-offs between product, process, and supply chain design. Many existing models have analysed the relationships between product architecture characteristics and supply chain decisions. The other model existing in literature helps deal with the selection of the appropriate sourcing strategy; whereas other models focus on the placement of the differentiation point in the supply chain [6].

Through literature studies, it has been identified that there is lack of evidence in comprehensive framework dealing with NPD-SCM alignment even though management needs a tool that explains the impacts of introducing new products on the supply chain. The tool aims to provide guidelines to management team depending on product features and enable them to identify the supply chain decision that leads to high performance. Based on these limitations within current technologies available, two research focus areas have been identified as:

(i) How to relate NPD and SCM variables with each other?

(ii) In reality, how can companies integrate NPD and SCM to gain high performance advantage within Supply chain?

For analysing these research areas, the research path has been divided into two stages. In a first stage, the literature studies dealing with NPD-SCM integration and their dependencies and formulation of generalised features of the framework on the basis of current available literature has been done. This identification of features of generalised framework, developed at an early stage of the research process, improved the understanding of how in supply chain new products are being affected. In second stage, an exploratory case study of OEM and Tier1 supplier relationship, to identify the key decision making points has been done. On the basis of these new findings, the features of generalised framework has been analysed and then finally combine the findings from the literature and the case study to develop the alignment framework and to formulate four key decision making points indicating the relationships between NPD and SCM variables, i.e. time, cost, capability and performance.

The key problem within automotive sector is, supply chain covers a wide area of business cycle whereas the new product development mainly relates only to in-house manufacturing. Therefore, linking the two attributes of the business, i.e., SCM and NPD, is not an easy task to accomplish, which is possibly the major reason that it has not been discussed in detail in existing literature.

The other issue which has been raised by the literature review is that there is substantial lack in literature for a detailed framework that demonstrates the linkage between SCM and NPD. Most business sectors need a tool which shows the impact of linking [7].

Furthermore, there is a lack of evidence exists which shows that research has been done in identifying and analysing the key decision making points in NPD – SCM business scenario. Therefore, the main goal to achieve in this research is, to investigate and then analyse the key decision making points in the integrated supply chain and then on the basis of this, to identify the functional requirement for the development of the methodology.

The research outcome could help plan product development schedules and choosing right suppliers based on the recommendation given by proposed framework. The other industrial benefit which can be achieved by this research is to improve the supplier capabilities by improving communications between OEM and suppliers while making feasibility decisions much quicker. The alignment of SCM and NPD should lead to an improvement in the performance of both the OEM and its supply chain [8]. It is argued that the Time to Market (TTM) and the cost of NPD can be reduced considerably by involving the support functions to a greater extent, and also earlier in the NPD process [9], [10].

The benefit of integrating are that it allows the manufacturer to overcome the problems like partially failed product introduction into the marker because of non-availability of that new product as they got insufficient capacities [11].

2. New product development

NPD has been of importance in most of manufacturing organisations. Actually there is no single model present which companies can use for new product development process [12]. But for a successful product development 5 factors are of great importance: good product quality, lower product cost, less development time, lower development cost, and effective development capability [13]. That is why; in current scenario where manufacturing is of prime importance these 5 factors become the targets to achieve.

NPD relates to most departments in the manufacturing companies. The department who defines product concepts as to meet customer requirements is Design; they are the one who creates realistic requirements after the approval of customer. Manufacturing function is basically an engineering department which defines the requirements for material purchase, distribution, and the whole supply chain.

3. Supply chain management

A supply chain is defined as "the integration of key business processes from end users through original suppliers that provides products, services, and information that adds value for customers and other stakeholders" [14]. Here, a supply chain includes all the value chain processes from suppliers to end customers.

It is vital that each supply chain participant adds value from the perspective of the end customer in the supply chain. This assumes integration of both supply and demand side activities in the value chain. Increasingly, the integration of both supply and demand requires an understanding of the inherent differences.

In this sense, [15] divided such integration into supply chain and demand integration. [16] Defined demand integrations as "integration that supports market mediation, with the primary role of demand integration being the transfer of demand information to facilitate greater responsiveness to changing customer needs." They argued that increased access to demand information throughout the supply chain permits rapid and efficient delivery, coordinated planning, and improved logistics communication.

As [17] described that according to The Supply Chain Operations Reference-model (SCOR®), endorsed by the more than 750 member companies of the Supply-Chain Council, breaks the outbound supply chain into four process elements:

(1) Plan; (2) Source; (3) Make; and (4) Deliver.

"Plan" includes all the supply chain activities related to demand management, sales and operations planning (S&OP), and overall supply chain strategy planning. "Source" covers the identification of supply sources and the execution of material and services sourcing on an on-going basis. "Make" covers all the conversion activities performed internally. Finally, "Deliver" includes the taking of customer orders and their fulfilment, including the management of the distribution infrastructure and outbound transportation.

Five critical performance levers have the greatest impact on supply chain performance: (1) Configuration; (2) Management practices; (3) External relationships; (4) Organisation; and (5) Systems.

The timeline of the concept of SCM in industrial background can be described as follows: [18].

1980's: Traditional Supply Chain

1990's: Lean Supply Chain

1995's: Integrated Leagile Supply Chain

2000's: Customised Leagile Supply Chain.

There is a lot of focus in supply chain research and literature on the need to integrate supply chains across companies. The reality in supply chains today however, is that companies are not even sufficiently integrated internally. In fact, how can enterprise integrate externally with other companies when they cannot even speak with one voice and are not even in agreement internally on priorities, plans and strategies? [19] points out that out of 12 drivers of supply chain performance internal alignment is the most fundamental starting point, without internal alignment all other drivers are useless to pursue.

The integration in the extended enterprise starts with the concept of Baseline Integration in which within the department the supply chain should be integrated. Then the next step is to functionally integrate the department. After this level of integration the enterprise can go towards the internal level of the integration in which now the whole company works in a same supply chain. And then the last stage comes which is of external integration, where different enterprises in the same supply chain links with each other.

Existing research has looked at improving internal alignment between marketing/sales and supply chain [20] but the new product development – supply chain interface within the company is crucially important as well. In particular in a time where there are pressures for growing product proliferation in order to meet varied demand, where the R&D pipeline is a key focus in companies and in a time where technology life cycles have shortened so much that obsolete inventories and time to market are crucial for R&D output and company margin performance. In that respect it is often pointed out that the impact of supply chain on new product development and product introduction is important in areas such as:

- Shipping product to market fast enough (before product launch dates);
- Ensuring sufficient inventory at the launch data; and
- Ensuring a flow of parts and components for new product manufacturing.

4. Automotive supply chain management

The automotive industry supply chain has been the subject of extensive research, but this has tended to concentrate on the component supplier-production sections of the chain. The industry has been at the leading edge of innovation in this area, with early adoption of new technologies such as EDI and business-to-business trading exchanges.

In contrast, the production-distribution sections of the chain have been the subject of relatively little academic research, and for many years the structure of the supply chain remained frozen in the pattern established by the middle of the last century. No matter how lean the assembly plants became, with component stocks reduced to a few hours, the distribution system remained "bloated" with typically 60 days of new cars either in transit or held at the dealers [21].

The new car supply chain presents a number of challenges, both for management and as a subject for research. For example:

- The complexity of the product – each individual car has a distinct specification in terms of body, engine, trim, colour, etc.
- The complexity of the supply network – multiple stocking locations from the assembly plant to several hundred dealers in each major market;
- Consumer behavior – including willingness to wait for a new car to be built-to-order, and the extent to which customers will compromise on specification;
- Demand seasonality – varying between markets, and its effect in combination with manufacturer's preference for level production schedules;
- Ageing of stock – resulting in heavy discounting to sell cars which remain unsold after several months.

The traditional downstream supply chain begins with production scheduling, with the objective of keeping production as stable as possible and ensuring that vehicles are financed by dealers as soon as they are produced.

This is achieved by maximising the allocation of orders to dealers at the earliest point possible – up to 60 days before assembly. Once the car is assembled, the vehicle is delivered

to the dealer as quickly as possible. The dealer's objective is to sell their available stock, if necessary using aggressive sales techniques to persuade customers to accept a car that is not their first (or even fifth) specification preference. This often involves additional discounts to the customer, encouraged by manufacturer incentives.

[22] Proposed that functional products should be matched with efficient supply chains, and innovative products matched with responsive supply chains. The downstream supply chain for new cars is based on manufacturers past perception of cars as functional products (due to the high volumes of production on a single assembly line). The car industry, therefore, endeavored to create an efficient supply chain type similar to other mass-produced consumer goods.

However, from the customers' viewpoint each car specification (including factors such as engine, colour, options, and trim level) is unique, even if it is the same model. Moreover, the range of body-styles has increased, with crossovers such as the sports-utility vehicle appearing, as has the speed of introduction of new models. Applying Fisher's criteria, cars are in the awkward position of combining features of both functional and innovative products, while the supply chain can hardly be described as either efficient or responsive.

The lean and agile approaches developed within the context of manufacturing in the early 1990s, and were subsequently applied to supply chain management. They have been defined succinctly by [23] as:

- Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place.
- Leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule.

[24] Points to the paradox of the automotive industry adopting lean manufacturing whole-heartedly, yet were having a supply chain that can be considered neither agile nor lean. Although originally considered mutually exclusive, [23] demonstrated that the two paradigms could be successfully combined into a single "leagile" supply chain, using the concept of the decoupling point to separate the lean (upstream) section of the supply chain from the agile (downstream) section.

This concept was quickly recognised as valuable in supply chain design, and in providing a mechanism for moving from the lean to agile models [18]. They have extended the original matrix of Fisher to incorporate a "hybrid" product type, giving automobiles as an example. The hybrid supply chain that is proposed as a desirable match for this product type is very similar to Naylor's leagile supply chain.

5. Integrating new product development and supplychain

The business rules have been changed nowadays, everyday new products and business are born. Customers are increasingly difficult to keep and costly to replace. Companies face intense competition from traditional powerhouses and new players, and must continue to find new revenue opportunities and increase efficiencies. The idea of integrating NPD and SC is not new as it has been discussed by a lot of researchers.

This relationship of NPD-SCM has got a lot of importance as it involves almost all the functional department within the extended enterprise. The main reason for consideration is that the design phase is a part of actual supply chain and it involves the cost also so if the enterprises can integrate them in a way that it will be cost effective, they can easily streamline the supply chain [25].

The main problem in a traditional supply chain is not sharing the exact information on a timely manner throughout the chain, which creates bull whip effect resulting distortion of information and in the end the cost of producing the product and then distributing it will be costly. So in order to make sure their decisions are aligned with the integration of SCM and NPD the SCM should be deigned in such a way that the products can be delivered within the targeted cost, time and quality [7]. NPD-SCM alignment is one of the major elements in a marketing strategy [24].

The products and services are the factors on which customers are judging the companies nowadays like for example Apple and its innovative products such as I Pad, on which they spend tremendous amount of resources to generate state of the art innovative product with the reliable services, just to catch the customers and the market share. At the end customers have got interest in looking in details for the evolution of these types of products and services.

Most of the R&D organisations do not view manageable inefficiency as a waste, but as a value-added activity necessary to get the design right. However, in reality, with companies around the world shows that excessive engineering work is a clear indicator of inefficiency and can be sharply reduced without an adverse effect on design outcomes.

Important issues in NPD and their influence on SCM have been summarised in Table 1.

Table 1. NPD - SCM connection requirement.

Requirement	Connection to SCM
A holistic view from strategy to commercialization	Different supply chain competences have to be involved in the NPD process to provide feedback. This also creates an opportunity to address NPD and SCD in parallel and as early as possible
Development of products based through market intelligence (customer oriented)	The provided supply chain solutions also need to be developed based on customer demand. This implies that companies when gathering information concerning needs of new products, also should collect information regarding service needs in order to develop the most appropriate supply chain solutions.
Development of products based on a segmentation model	Customers' requirements may also differ when it comes to lead-times and service levels, as well as preferred supply chain solution, implying that several solutions are required to become successful in the market.
Development of new and innovative products in accordance with customer preferences	Unwise to restrict innovation to products, other areas should also be included, such as supply chain solutions. These issues need to be considered in the NPD through involvement of supply chain representatives and by establishing information exchange between NPD and SCM.

Developing products rapidly and moving them quickly and efficiently to the market	Time-to-market is not solely determined in the NPD process but also in, sourcing, manufacturing, and distribution. This implies that supply chain representatives should be involved early in the NPD process to shorten time-to-market
Incorporating all the activities supporting commercialization (integrative NPD approach)	SCM and NPD need to be coordinated to successfully introduce products on the market, to ensure that the product assortment is updated according to product life cycles, and to ensure that obsolete products are properly out-phased.

Many companies consider NPD as a key strategic activity and a short time to market (TTM) as critical to long-term success. The majority of research in this field has focused on issues such as reduction of the TTM and process improvement issues in isolation [26], [27].

However, research addressing the coordination of NPD and supply chain management (SCM) as necessary for bringing new products to the market is relatively rare [9], [11]. For instance [5] commented that the literature addressing NPD and production ramp-up is sparse, although notable exceptions exist.

For this reason, companies need to stop thinking around the edges and begin to coordinate and address these issues in parallel to reduce the TTM as well as to enhance profitability [10]. SCM should no longer need to clean up after NPD, but instead be involved from the beginning of product development, with the same level of authority [11].

There is a lack of research examining how the different NPD and SCM activities influence each other, how they can be coordinated, what benefits that can be obtained by coordinating them, and what the requirements are to succeed with the coordination [9], [10] and [11]. This means that there is a need for research aiming to increase the understanding of the whys and how's of NPD and SCM coordination.

5.1. Key decision making points

During the recent swift progress of network technology and economic globalization, modern automotive industry has been trending towards the increasingly precise division of labour. Consequently, individual enterprises focus on developing their core capabilities and outsource non-core affairs to other partners or suppliers with different professional capabilities to upgrade their competitive advantage by applying these external and special sources and technology knowledge.

On the other hand, consumer- behaviour is widely changed because of the increasing consumers' ideology; hence, product lifecycles are becoming shorter and every enterprise must offer diverse and custom made products to immediately satisfy consumer needs.

These pressures drive automotive enterprises to actively invest in supply chain management (SCM), and to establish strategic alliances against their competitors. Generally, SCM occurs when several enterprises establish their own supply chain. These enterprises must find more efficient suppliers to increase supply chain competitiveness. Among various available suppliers, how to choose more collaborative suppliers who can develop long-term relationships is a key issue in establishing a supply chain and enhancing its efficiency.

Many previous studies on has been done in decision making selection and evaluation. For example, [28] has surveyed companies to identify factors they considered in awarding contracts. Out of the 23 factors considered, Dickson concluded that feasibility, time, cost and capability performance are the four most important criteria.

Another study by [29] derived key decision making points thought to influence the decisions like Make/Buy decisions. These factors were taken from 74 related articles that have appeared since Dickson's well-known study.

Based on a comprehensive review, they summarised that feasibility was the highest-ranked factor, followed by time, cost and capability performance.

These empirical researches revealed that the relative importance of various decision criteria such as feasibility, time, performance and cost is similar. So basis on this existing research the following factors have been chosen to do this research:

- Feasibility,
- Time,
- Cost,
- Capability and Performance.

6. Integrated framework

The idea of integrating product development phases in supply chain has got so many different aspects, including the one which is focused that is, to identify the key decision making points in OEM and supplier relationship. First, the aspects of new product development and then the supply chain processes of an automotive firm through AS - IS situation has been analyzed. Based on the simple supply chain concept of supply chain in which product starts from customer requirement and goes to the final stage where it has been delivered to customer in a market. The features of product development have been linked with the features of supply chain to get the benefits of the improved performance of the extended enterprise.

As the literature suggests that supply chain covers the whole business aspects of the extended enterprise from suppliers' supplier to the customers' customer. So in order to integrate the features of SC, the four basic drivers of supply chain (information, facilities, inventory and transportation), supply chain design (competitive or flexible w.r.t time response) and the supplier relationship has to linked up with the features of product development. On the other hand product development looks after only manufacturing aspect of the enterprise, so the features which can be linked are related to product manufacturing only. The Figure1 shows the overall view of the integrated NPD – SCM enterprise, which will enhance the performance in several aspects, which has been discussed in existing literature.

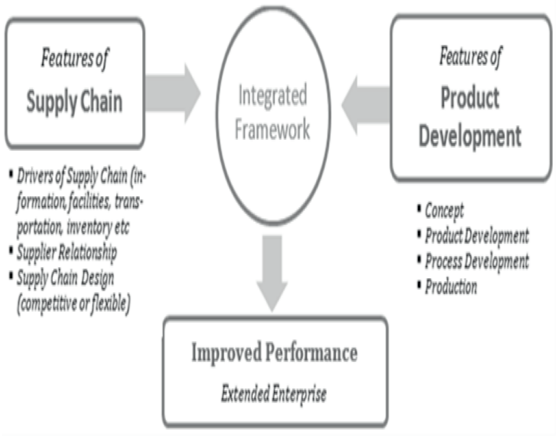

Fig. 1. Idea of framework to integrate features of supply chain with product development.

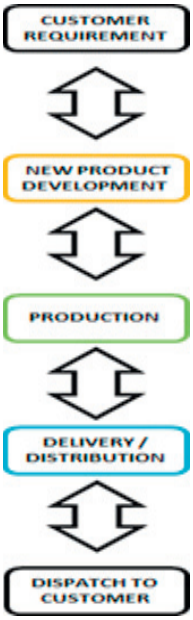

Fig. 2. Typical Product Development and Manufacturing Activities.

The framework is derived from the generalised process extracted from AS – IS process. The basic activity which starts from customer requirement that leads to product development process and then production. After production, the delivery/distribution departments deliver the product to customer. These typical activities are shown in Figure 2.

After placing the basic activities in initial idea of generalised framework, to make it more business oriented, it has been transformed into Figure 3, which illustrates the starting of the generic process between OEM, Tier 1 and Tier 2 suppliers. By looking at Figure 3, the relationship between OEM with suppliers is quite clear. In this research, the OEM (car assembly)'s Product development processes has been interlinked with OEM (sub-assembly engine block) product development processes.

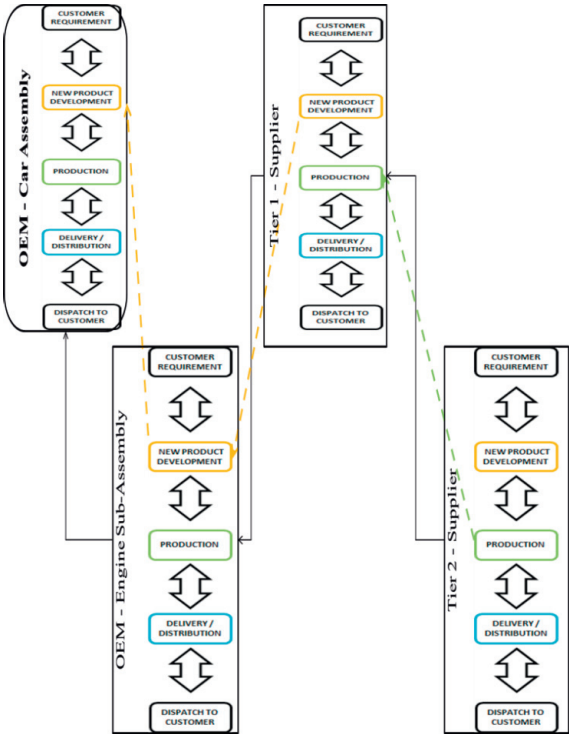

Fig. 3. Initial idea of generalized framework within SCM Context.

Engine block sub-assembly parts of OEM's PD processes are directly linked with Tier 1 supplier's PD processes, which is the main focus of this research. They work together with OEM on product development processes. Furthermore, Tier 1's production processes are interlinked with Tier 2 product processes. After analysing this relationship of OEM with Tier 1 and Tier 2 supplier, the generalised framework has been proposed which shows the true linkages among them in Figure 4.

6.1. Description of framework

This research analyzed the extended enterprise basic business processes, starts from customer requirement and leads into the new product development phase which gives instructions to the production department. After producing the product, the information goes into the delivery/ distribution department which eventually deliver the product to customer on requirement. The Proposed framework is shown in Figure 4.

By looking at the details of the extended enterprise in this research, the OEM generalized product development processes in the proposed framework which starts from program initiation step then goes in the program planning step.

Then after confirming the product, its design has to be validated according to design requirement. In the end, before it goes into the step of production, the process has to validate also according to the requirement generated in the early stages of NPD.OEM (car assembly)'s generalised PD processes are

linked with OEM (Engine block sub-assembly)'s PD processes which has got the same generalised PD processes like the OEM (car assembly) but with different detailed PD processes which is also linked with the same colour coding. In OEM (engine block sub-assembly), the process starts off with the first phase of program initiation which is divided into four processes.

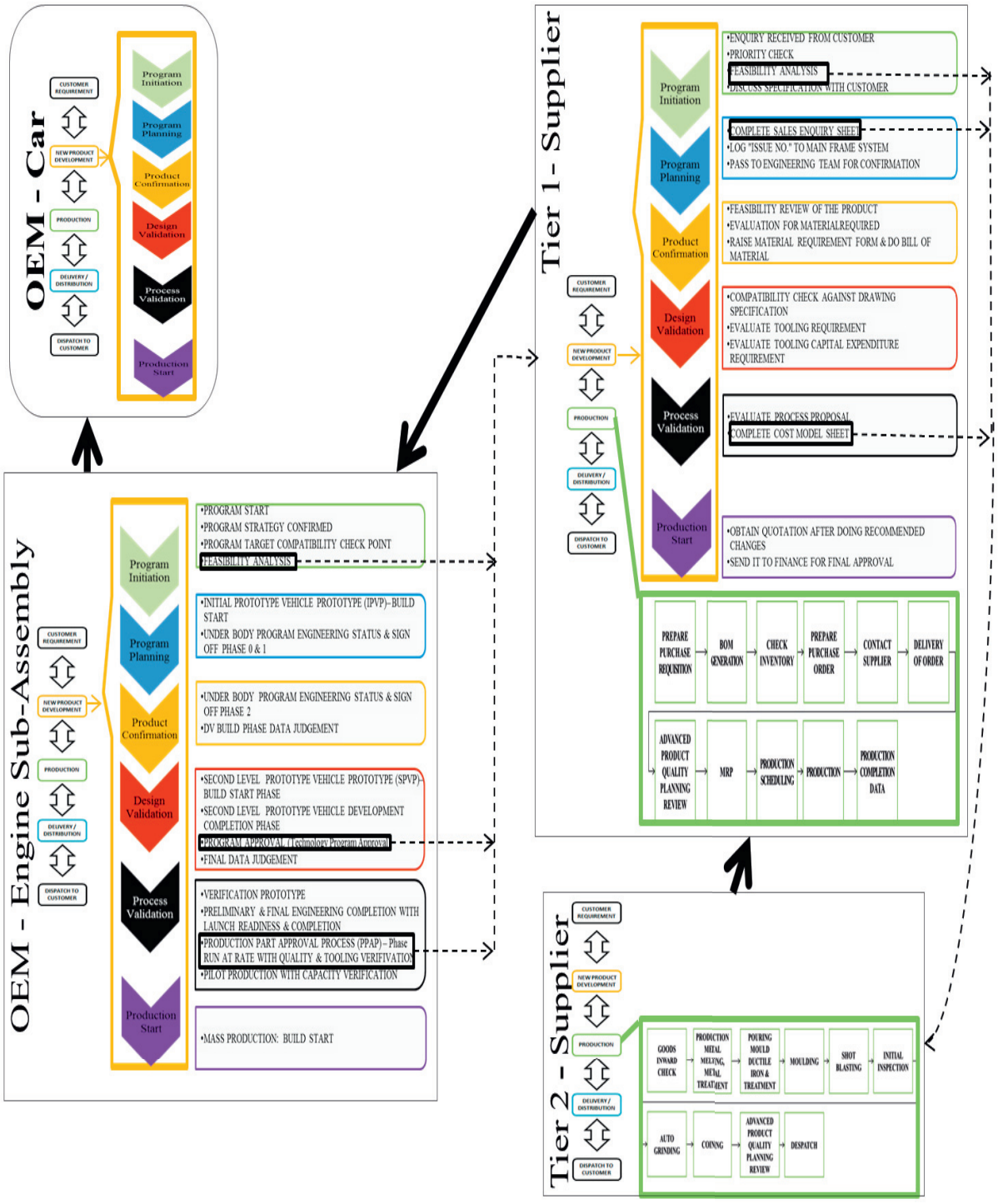

Fig. 4. Detailed Collaborative framework in Product Development within Global Supply Chain.

First process is program start which leads into program strategy confirmation process which further goes into the program target compatibility check process and finally in the last process of the first phase is feasibility analysis. The detailed framework has been shown diagrammatically in Figure 4, which shows the true linkages among the OEM (Car Assembly), OEM (Engine Block Sub-Assembly), Tier 1 Supplier and Tier 2 supplier.

In the second phase i.e. Program planning phase, it can be divided into two processes. In first process of Initial prototype vehicle prototype (IPVP) the OEM does the build start stage which leads them into the next process of IPVP – Phase. Then the process comes of under body program, where under body engineering Phase 0 and then Phase 1 has been sign off.

Furthermore in the third phase of product confirmation, the OEM has divided it into two processes i.e. signing off the under body program phase 2 and then DV Build phase and Data judgment. The fourth phase design validation, has been sub divided into four processes i.e. Generation of second level prototype vehicle prototype (SPVP)-Build start, and then its complete sub phase. In the next process, the second level prototype vehicle development has to be completed and then in it goes for approval through technology program approval. In the last process it goes for final data judgment.

In the fifth phase of process validation, the OEM has divided it into four processes. Initially it starts with building of verification prototype which leads it into preliminary engineering completion. Then the final engineering completion step comes in play which creates launch reediness in the product line and then it goes for launch sign off step. Then in the process of production part approval phase 0 the product finally goes for quality verification in the next process of this phase. Later the step of tooling trial comes in play which leads the product into production verification through pilot production. In the last process of this phase, the capacity has been verified which send the product in the last phase of production start.

In the sixth phase of production start, the product starts off with mass production 1 build, leading it into job 1 step and finally mass production 2 build which ends the product development process at the OEM (Engine block sub-assembly)'s end.

In the proposed framework, it has been shown that the OEM (engine block sub-assembly)'s PD processes are interlinked with Tier 1's PD processes. To understand the Tier1's PD process, it is to be divided into the same generalised PD processes. In a first phase of program initiation, the Tier 1 supplier cross check the priority of that order. If it is required to send it through, then the detailed specification has to be discussed with the OEM (engine block sub-assembly). Then in the next process, the feasibility analysis has to be done which is the main focus of this research.

Then in the next phase of program planning, the sales department sends it to sales administration which loads this request into the main frame of the company and then passes it to the engineering administration department. In the third phase of product confirmation, when it reaches the engineering department, they have to generate the MI (Material Information) and BOM (Bill of material) of that part.

In the fourth phase of design validation, for BOM they need to analyse the engineering drawing and then after cross checking the inventory, they contacts the purchasing department if required to order more material. On the other hand for MI, engineering department evaluates the tooling capital expenditure and process proposal.

In the fifth phase of process validation, the engineering department completes the cost model sheet which includes the overall cost of the production and sends it to finance department for authorisation.

In the last phase of production start, the finance department does the cost benefit analysis and gives approval or disapproval to the company based on the recommendation of the entire concerned departments. As a whole in the above process, company's sales, engineering and purchasing departments are involved.

At the same Tier 1 supplier's end, the production process has been interlinked with Tier 2 supplier's production process. Tier 1's production process, has been divided into several key important sub processes. It starts with the preparation of the purchase requisition based on the Bill of Material (BOM) which is generated in the second sub process. Then in the next process, the inventory has to be checked and then if required purchase order has to be generated and sends it to the supplier, who delivers the order back to production department which then does the Advanced Product Quality Planning Gateway Review, which is the main focus of this research, in production processes. In this APQP review process, the Tier 2 Supplier has been interlinked with Tier 1 supplier. Then in the next process of Tier 1's production process, Material Requirement Planning (MRP) has to be generated. This MRP facilitates the scheduling of the production which eventually gives the information to the production department to manufacture that part and finally in the end after production the data has to be generated which links the delivery/ distribution process of OEM to take the product for final assembly.

The Tier 2 supplier's end where the casting has been done as a production process has been interlinked with Tier 1's production process. At Tier 2 end, the production process starts with includes 15 sub processes, which starts from incoming of goods which are in shape of steel scrap. After having a quality check for different processes like pig iron, furnace additions and sand moulding at the incoming stage, the process goes in the metal melting phase. In the next process it goes in the metal treatment phase which leads to the process of pouring the molten metal into the moulds.

Furthermore it goes in the sub process of greensand moulding and after that it goes through the sub process of shot blasting. Then it goes in the initial inspection phase, where the quality aspects can be cross checked according to the customer requirement. In the next stage it goes into the auto grinding where the automatic grinding machine removes the remaining wastages and brings the part into the desired level of customer.

After that process, the part goes into the phase of coining (pressing operation) and then before packaging and sending of

part to the customer it goes into the second last stage APQP review process as the final quality check with Tier 1's production department which is the main focus of this research. Then the product has to be shifted into the warehouse which then informs the logistics provider (either in-house or 3pl) to create the delivery order and finish the business process by delivering the product to the Tier 1 supplier of the OEM.

7. Conclusion

This research introduces the development and analysis of the framework that allows the integration of the flow of product development related activities within original equipment manufacturers (OEM) and suppliers thus providing future business benefits.

The proposed framework use key drivers to predict and quantify its impact on the four main criteria namely: feasibility, time, cost and capability that support or advise on key decision making of OEM's product development and management teams.

The further dimension of this research can lead to develop an ideal development of methodology for NPD-SCM integration based on enterprise framework for everything in enterprise rather than just for new product development. Therefore, in future, other Enterprise framework methodologies can be merged within this proposed framework.

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