Fachbereich Wirtschaftswissenschaft

Supply Chain Management of Mass Customized Automobiles

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Declaration

I declare that this thesis has been composed solely by myself and that it has not been submitted, in whole or in part, in any previous application for a degree. The work was made without unauthorized aid. No other than the specified sources and aids were used. Except where states otherwise by reference or acknowledgment, the work presented is entirely my own.

Date & Place

27th May 2019, Bremen

Signature of author

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List of Abbreviations

3CDN ..... Level 3 content delivery network 83
3PL ..... Third party Logistics provider 36
B2B ..... Business to business 81
BMW ..... Bayerische Motoren Werke 16
BOSC ..... Build to order supply chain 33
BRIC ..... Brazil, Russia, India, china 67
BTO ..... Build to order 02
BTS ..... Build to Storage 43
CE ..... customization extent 154
COSO ..... Committee of Sponsoring Organizations of the Treadway Commission 99
Dd ..... Distribution distance 125
DdP ..... Distribution Division in Production 124
DdS ..... Distribution Division in sales 125
DWDM ..... Dense wavelength Division multiplexing 83
EBIT ..... Earnings before Interest and Tax 122
FAST ..... Future Automotive Supply Tracks 94
FTS ..... self-governing driverless transport system 94
FIM ..... Fully integrated module 37
GM ..... General Motors 35
GRC ..... Governance, risk and compliance 100
IAC ..... International Automotive Components 105
IC ..... Individual collection 51
IF ..... Inventory Inventory of finished products 124
IR ..... Inventories of raw material 124
ISO ..... International Organization for Standardization 88
IW ..... Inventory of work in progress 124
JIS ..... Just in sequence 81
JIT ..... Just in time 19
LDP ..... change in distriction distance in production 142
LDS ..... change in distributional distance in sales 142

LF ..... change in finished good inventories 142
LR ..... Change in raw material inventories 142
LSDV ..... Least square Dummy variable137
LW ..... change in work in progress inventories 142
MCC .....Mass customization capability 32
MSP ..... Master Scheduling Program 116
MTO .....Make to order 43
OECD ..... Organisation for Economic Co-operation and Development 97
OEM .....Original equipment manufacturer 23
PIM .....Partially integrated module 38
SSI .....Sales satisfaction index 126, 155
SuRe.....Supplier relation index
US .....United States 34
WRI .....Working relation Index 104

1 Introduction

1.1 Research motivation

In August 2016, hardly few months after Volkswagen AG was affected by the emission scandal, the company faced another interruption in the supply chain. A dispute with the Bosnian supplier halted the production of mass customized automobiles in almost half of the German plants. As the supplier was providing customized car seats, it was not possible for the company to look for a new supplier in a short period[1]. This crisis was due to a high dependence on the supplier (who was providing mass customized seats). This issue halted the car production in half of the Volkswagen AG plant. Furthermore, it put the company further into crisis with labour when it reduced the labour hours due to less production. This high reliance on a supplier is not only the part of Volkswagen AG's supply chain but is one of the characteristics of the modern supply chains approaches in automotive industry.

In the automotive industry, there is a long history of crises due to disruptions in the supply chain. Likewise, in December 2001 a similar scenario happened with Land Rover Discovery Model, as the only supplier of the company filed for bankruptcy[2]. Such disruptions are not always from the first-tier supplier but also can be associated with the linkages in the supply chain, e.g. in 2005 Robert Bosch GmbH had provided car manufacturers with the defective pressure pumps but later it was found out that the problem occurred because the sub-supplier of Robert Bosch GmbH provided them with the faulty part. Such a problem from one member can affect the whole supply chain and can cause losses of millions euros, the problem becomes more profound when the supplier is the only supplier and provides a customized product.

It is important to consider that with the adoption of mass customization any problem with the suppliers can lead to drastic results. More importantly, if the supplier is providing the customized parts, it is not possible to look for the alternative supplier in a short span of time.

Mass customization is getting more popular in modern times in European countries. More profoundly after the evolution of the computer industry, the wave has transferred to German automobile compa-

[1] https://www.forbes.com/sites/neilwinton/2016/08/30/volkswagen-supplier-dispute-might-foreshadow-deeper-industry-problem/#4697d474497c Seen on Nov 2016

[2] Thun, J. H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. International Journal of Production Economics, 131(1), 242-249. ; Sheffi, Y., & Rice Jr, J. B. (2005). A supply chain view of the resilient enterprise. MIT Sloan Management Review, 47(1), 41.

nies. An important phenomenon faced by the automobile industry is highly variable choices for customers. With the increasing fashions and media progress customer preferences are becoming more different, thus almost all of the automobile manufacturers give their customers options to customize their own car. An automobile (through mass customization) can be offered in a high number of variants, with multiple options in engine types, styles, transmission, colours, trims and various other selectable options[3]. In recent times, there is not only an increase in the customization options, but automobile companies also sought to reduce delivery times, increase responsiveness and reliability in the supply chain. A major example is of BMW AG that spent about €55 million to reduce the delivery time by 20 days. Similar examples are seen in other German automotive companies also[4].

Although the concept of mass customization got popular in short span of time, but it has never been an easy job for the automotive industry. This was the reason that the automotive industry moved from customization to mass production in 1913[5]. If mass customization is not carried out with efficient supply chain policies, it can result in a decrease of customer satisfaction (contrary to its claims)[6].

In modern times, process of mass customization is linked with the production process "Build to order". By the start of the 21st century, there was a high trend in German automobile companies to invest in the progression of Build-to-Order (BTO) cars. In this process, production starts after the order comes, so the company is uncertain about future demand pattern[7]. Hence, the process is linked with high level of uncertainties. As the customers demand is becoming more and more unpredictable, firms need to have a higher capacity, more flexibility and lean systems to fulfil such demands. Thus, to deliver the right tool at the right time at the right place has never been as important as now[8].

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[3]Brabazon, P. G., MacCarthy, B., Woodcock, A., & Hawkins, R. W. (2010). Mass customization in the automotive industry: comparing interdealer trading and reconfiguration flexibilities in order fulfillment. Production and Operations Management, 19(5), 489-502; Fredriksson, P., & Gadde, L. E. (2005). Flexibility and rigidity in customization and build-to-order production. Industrial Marketing Management, 34(7), 695-705. ; Meyr, H. (2004). Supply chain planning in the German automotive industry. Spectrum, 26(4), 447-470.

[4]Meyr, H. (2004). Supply chain planning in the German automotive industry. Spectrum, 26(4), 447-470.

[5] Holweg, M. (2008). The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33.

[6]Ahlstrom, P., & Westbrook, R. (1999). Implications of mass customization for operations management: an exploratory survey. International Journal of Operations & Production Management, 19(3), 262-275.

[7]Pollard, D., Chuo, S., & Lee, B. (2016). Strategies for mass customization. Journal of Business & Economics Research (Online), 14(3), 101.

[8]Ericsson, R., Becker, R., Döring, A., Eckstein, H., Kopp, T., Poslu, I., &Vancza, J. (2010). From build-to-order to customize-to-order. Advancing the automotive industry by collaboration and modularity. Code of practice findings of the EU-FP6 Project AC/DC-Automotive Chassis Development for 5-Days Cars Consortium of the AC/DC project, 112.

Mass customization demands high flexibility in the system to cope with uncertainty and variability, research shows that flexibility of supply chain is a major contributing factor towards successful mass customization[9]. However, the financial crisis of 2008 showed that automotive does not give focus on flexibility while pursuing the supply chain management[10]. Although the European automotive industry has applied several techniques to increase flexibility in the system, the changes were not enough to cope with the financial crisis of 2008. The fluctuations caused by the financial crisis impacted suppliers, manufacturers and market demand. Due to a lack of responsiveness in the supply chain, less communication between the supply chain partners and less flexibility, the crisis had led to extreme management inconsistencies that further resulted in shortages, production lines disruptions and high emergency logistics costs[11]. Another challenging situation for the European automotive industry was that at the same time, when the automotive industry in Europe was suffering from crisis in 2008, new industries in India and China began growing much faster. These industries were also more capable to achieve the international standards[12].

Although the German automotive industry is considered as one of the most stable automotive industry globally, however studies showed that most of the German automotive companies are exhibiting vulnerable supply chains[13]. Various risky policies like outsourcing, reduced number of suppliers and globalization are common in German automotive industry this has many times lead to high risked situations[14]. Hence, it has becomes very important for the business actors to develop strategically flexible

[9]Brabazon, P. G., MacCarthy, B., Woodcock, A., & Hawkins, R. W. (2010). Mass customization in the automotive industry: comparing interdealer trading and reconfiguration flexibilities in order fulfillment. Production and Operations Management, 19(5), 489-502.; Bremmer, R. (1999) Cutting edge platforms. Financial Times Automotive World, September, 30–38; Carey, M. (1997). Modularity times three. Sea Power, 40(4), 81-84.

[10]Brabazon, P. G., MacCarthy, B., Woodcock, A., & Hawkins, R. W. (2010). Mass customization in the automotive industry: comparing interdealer trading and reconfiguration flexibilities in order fulfillment. ProductionandOperations Management, 19(5), 489-502.

[11] Ericsson, R., Becker, R., Döring, A., Eckstein, H., Kopp, T., Poslu, I., &Vancza, J. (2010). From build-to-order to customize-to-order. Advancing the automotive industry by collaboration and modularity. Code of practice findings of the EU-FP6 Project AC/DC-Automotive Chassis Development for 5-Days Cars Consortium of the AC/DC project, 112.

[12]Ericsson, R., Becker, R., Döring, A., Eckstein, H., Kopp, T., Poslu, I., &Vancza, J. (2010). From build-to-order to customize-to-order. Advancing the automotive industry by collaboration and modularity.Code of practice findings of the EU-FP6 Project AC/DC-Automotive Chassis Development for 5-Days Cars (p. 112). Consortium of the AC/DC project.

[13] Thun, J. H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. International Journal of Production Economics, 131(1), 242-249.

[14]http://www.telegraph.co.uk/business/2016/08/22/vw-suspends-production-at-six-german-plants-over-supplier-row-wh/ Seen on Nov 2016

conditions which allows different strategic options to respond to the changes[15]. However, the history of crises faced by the automotive industry shows that strategic flexibility in the supply chain has still not been fully developed.

From the point of view of automotive companies, it has never been an easy job to provide customer with their choice[16]. The focus of mass customization is to meet individual customer demand with minimal loss of efficiency[17] so to target efficient mass customization; the firm should be able to provide high level of product variety and the good delivery lead-time and without losing efficiency. While the studies have shown that, there exist a trade-off between levels of customization offered, costs, and delivery lead times[18]. Moreover, the complexity in the production line is increasing, especially in regard to how the customized automobiles are equipped, more and more variety is fragmented in the niches of traditional car segments, the diversification in the variety is increasing, which is causing high complexity in the supply chains[19]. Moreover, to meet the challenging situation, manufacturers prefer to distribute their production capacity worldwide which enables them to understand local market conditions, lower production and logistics costs and improved customer services[20]. However, extended

[15] Brozovic, D. (2018). Strategic flexibility: A review of the literature. International Journal of Management Reviews, 20(1), 3-31.

[16]Brabazon, P. G., MacCarthy, B., Woodcock, A., & Hawkins, R. W. (2010). Mass customization in the automotive industry: comparing interdealer trading and reconfiguration flexibilities in order fulfillment. Production and Operations Management, 19(5), 489-502. ; Holweg, M., & Pil, F. K. (2001). Successful build-to-order strategies start with the customer. MIT Sloan Management Review, 43(1), 74.

[17]Liu, G., & Deitz, G.D. (2011). Linking supply chain management with mass customization capability. International Journal of Physical Distribution & Logistics Management, Vol. 41 Iss: 7, 668 – 683.

[18]Brabazon, P. G., MacCarthy, B., Woodcock, A., & Hawkins, R. W. (2010). Mass customization in the automotive industry: comparing interdealer trading and reconfiguration flexibilities in order fulfillment. Production and Operations Management, 19(5), 489-502.; Cousins, P. D., Lawson, B., & Squire, B. (2006). Supply chain management: theory and practice–the emergence of an academic discipline?.International Journal of Operations & Production Management, 26(7), 697-702.

[19]Leskova, A. (2012) Build-To-Order Principle Of Customized Production In The Field Of Automotive, Transfer inovácií

[20]Yinan, Q., Tang, M., & Zhang, M. (2014). Mass customization in flat organization: The mediating role of supply chain planning and corporation coordination. Journal of Applied Research and Technology, 12(2), 171-181. ; Liu, G., Shah, R., & Schroeder, R. G. (2006). Linking work design to mass customization: a sociotechnical systems perspective. Decision Sciences, 37(4), 519-545.; Nigro, G. L., Bruccoleri, M., & Perrone, G. (2006). Negotiation in distributed production planning environments. International Journal of Production Research, 44(18-19), 3743-3758.

network in different places and distributed production system creates problems with supply chain partners[21]. As a result, it has become difficult to manage efficiency in the system while meeting the challenges. Although, supply chain management has been considered as one of the major challenges in the implementation of mass customization, it can lead to high profits if it is managed efficiently. Volkswagen AG claimed to save $1.7 billion annually through effective mass customization operations in late nineties[22].

Many important factors upon which mass customization rely such as flexibility, responsiveness and lead time can be controlled optimally with supply chain[23]. In other words, to run a successful mass customization, it is very important to run an efficient communication with suppliers, rapid coordination between suppliers and producers and a well-integrated logistics system[24]. In order to manage the supply chain, and to produce BTO cars in minimum time, and minimum cost automotive industry has experimented different practices. Just in time (JIT), integrated supply chain, Modular approaches and different other techniques have been applied by automotive industry in past decades to make the supply chain as efficient as possible[25]. However, the automobile industry has not been able to apply same method for a long time as rapid changes in techniques and scenarios make situations dynamic. Table 1-1 shows the timeline of different techniques and the crises faced in those times. If we look at the time line for mass customization and matching supply chain policies, it is observed that Mass customization got popular in late nineties, and along with that JIT and lean supply chain became one of the popular approaches towards supply chain. Integrated supply chain and modular consortia approaches were incorporated in supply chain with advances in the research. However, it did not occur that the same approach in the supply chain was operational for a long time, this lead to inconsistent approaches.

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[21]Yinan, Q., Tang, M., & Zhang, M. (2014). Mass customization in flat organization: The mediating role of supply chain planning and corporation coordination. Journal of Applied Research and Technology, 12(2), 171-181. ; Nigro, G. L., Bruccoleri, M., & Perrone, G. (2006). Negotiation in distributed production planning environments. International Journal of Production Research, 44(18-19), 3743-3758. ; Galasso, F., Mercé, C., & Grabot, B. (2009). Decision support framework for supply chain planning with flexible demand. International Journal of Production Research, 47(2), 455-478.

[22]Gershenson, J. K., Prasad, G. J., & Zhang, Y. (2003). Product modularity: definitions and benefits. Journal of Engineering design, 14(3), 295-313.

[23]Yinan, Q., Tang, M., & Zhang, M. (2014). Mass customization in flat organization: The mediating role of supply chain planning and corporation coordination. Journal of Applied Research and Technology, 12(2), 171-181.

[24] Berman, B. (2002). Should your firm adopt a mass customization strategy?.Business Horizons, 45(4), 51-60.

[25]https://www.researchgate.net/profile/Silvio_Pires/publication/223075250_Outsourcing_in_the_Automotive_Industry_From_JIT_to_Modular_Consortia/links/547716be0cf245eb43729cd5/Outsourcing-in-the-Automotive-Industry-From-JIT-to-Modular-Consortia.pdf Seen on Nov 2016

Year	Mass customization (MC) trends	Supply chain Techniques	Crisis faced
1990-1995	Not popular	JIT	Supplier caused disruptions
2000-2004	Success of computer industry, popularity in other industries	JIT, Integrated supply	
2005-2010	BTO approach in automotive industry	JIT, Integrated supply, outsourcing	BMW AG Pumps scandal
2015-2017	BTO popularity	High trend of partner ships, Outsourcing, modularization	Volkswagen AG seats scandal

Table 1-1: Time line of MC trends, SCM policies and crises

The different techniques shown in Table 1-1, has different attributes, the relationships between producer and supplier are different in all of them. Outsourcing was increased with the progress in modular approach, which resulted in increased dependence upon the supplier. Therefore, in modern supply chain structures the major value creation is attributed towards supplier. Studies shows that nowadays about 70 to 80 % of the whole value creation is attributed towards supplier[26]. The crises that Volkswagen AG faced were also due to this high reliance on the supplier. Higher dependence on supplier increases the risk factors while the higher number of suppliers means more managerial issues. The supplier and producer relationship in different approaches of supply chain has been summarized in Table 1-2. There are many suppliers in the case of simple JIT and the relation between OEM and supplier is independent. Also in the case of integrated supply, there is independent relation between first tier supplier and OEM, however in the case of Modular Consortia the supplier is co-investor so the relation is not independent anymore. The location of supplier and other conditions are also different in all these three techniques as shown in table.

[26]Bennett, D., & Klug, F. (2012). Logistics supplier integration in the automotive industry.International Journal of Operations & Production Management, 32(11), 1281-1305.; Harrison, A., & Van Hoek, R. I. (2008). Logistics management and strategy: competing through the supply chain. Pearson Education.

Characteristics	JIT	Integrated supply	Modular Consortia
Suppliers	Several	First tier	Co-Investors
Location	Proximate, with geographic separation	On-site, no geographic constraint	On-line with no geographic constraint
Relationship	Independent	Independent	Dependent
Logistics	Effect coordination	Increase efficacy	Increase efficiency
System Flexibility	Possible to reconfigure	Limited ability to reconfigure	Limited ability to Modify partnership

Table 1-2: Different supply chain approaches and their characteristics
Source: Collins, R., Bechler, K., &Pires, S. (1997) [27]

With the adoption of modern techniques dependence upon supplier is increasing, thus it has become very important for automotive companies to have control on different supply chain relation, otherwise problematic situations can occur, (as faced by Volkswagen AG).

1.2 Research gap and research questions

Since automotive industry, with the move towards mass customization is moving towards the approach of less suppliers, outsourcing, involvement of supplier in production, modular parts being supplied form the supplier it can lead to the crisis more often. The dynamics in supply chain policies leads to difficult managerial situations. Studies have already showed that German automobile industry is exhibiting vulnerable supply chain but most studies investigate the supply chain on plant level and not central supply chain policies[28]. The studies in literature were focused on the determination of the risk

[27]Collins, R., Bechler, K., &Pires, S. (1997). Outsourcing in the automotive industry: from JIT to modular consortia. European management journal, 15(5), 498-508.
[28]Yinan, Q., Tang, M., & Zhang, M. (2014). Mass customization in flat organization: The mediating role of supply chain planning and corporation coordination. Journal of Applied Research and Technology, 12(2), 171-

in supply chain on the plant level[29]. However central supply chain policies have significant role in efficiency as these policies (based on mutual interest of stake holders) would enable manufacturer to understand better forecasting of customers' trends and suppliers capabilities, this will reduce the risks of uncertain changes. When the policies are viewed upon the central level, and not for individual plants, it would enable to investigate the impact of external partners. This is broader prospect as the plants are dependent upon the external partners for knowledge and resources[30].

Furthermore, it is interesting to note that different automotive companies in Germany are having control over supply chain differently. For example BMW AG make partnerships with suppliers (sometimes on equivalence bases) while Volkswagen AG still prefer many in-house operations thus does not treat suppliers with same weightage. It is worthy to compare the differences in policies determine best supply chain practices in the industry. This is the basic research motivation behind this study, which is also shown in Figure 1-1

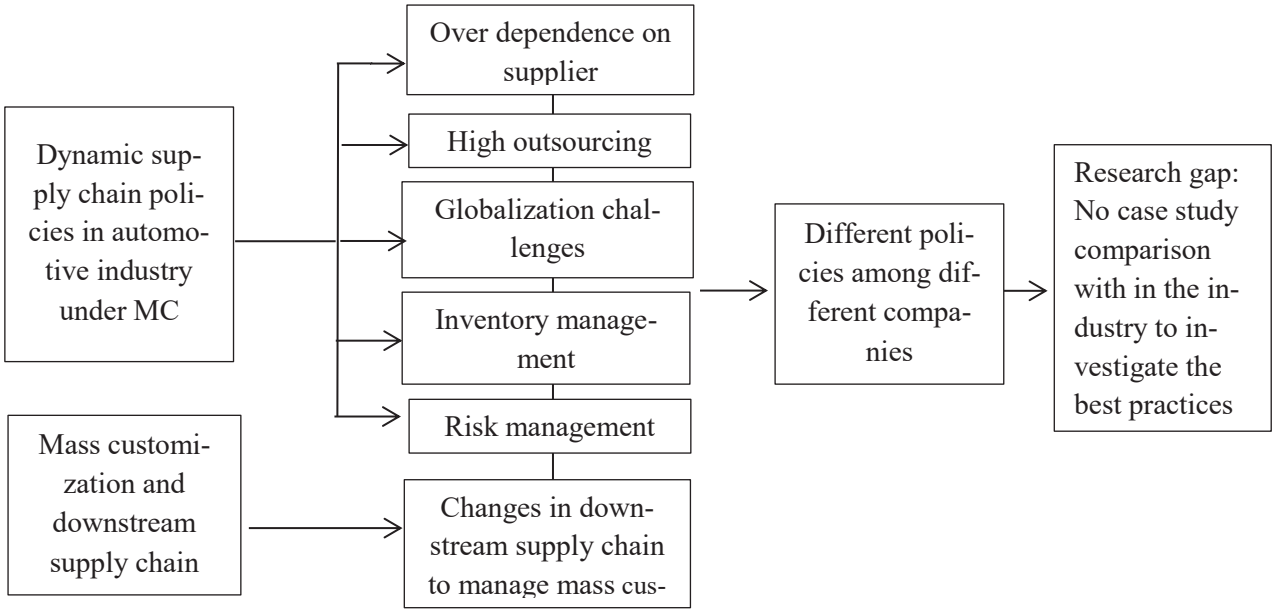

Figure 1-1: Research motivation and research gap

181.; Rungtusanatham, M. J., & Salvador, F. (2008). From mass production to mass customization: Hindrance factors, structural inertia, and transition hazard. Production and Operations Management, 17(3), 385-396. ;Kotha, S. (1995). Mass customization: implementing the emerging paradigm for competitive advantage. Strategic Management Journal, 16(S1), 21-42.

[29] Thun, J. H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. International Journal of Production Economics, 131(1), 242-249.

[30]Yinan, Q., Tang, M., & Zhang, M. (2014). Mass customization in flat organization: The mediating role of supply chain planning and corporation coordination. Journal of Applied Research and Technology, 12(2), 171-181.

For this purpose, this study will investigate central supply chain policies in German automotive industry, which is exercising mass customization from over a decade. In this regard, the following research question is established:

Which supply chain practices are most efficient under modern mass customization in automotive industry? To be more specific, this question can be sub divided into following parts:

1. Which practices lead to efficient supply chain management under mass customization? (in major three automotive companies)
   - What are Supply chain strategies, practices and risks in mass customized environment
   - What kind of policies make supply chain more vulnerable in mass customized environment
   - How much the modern Original equipment manufacturer(OEM) is dependent upon supplier
   - What are the risk measures to avoid interruptions in the supply chain
   - How the policies are different among different automotive companies
   - Which practices are more sustainable in supply chain
2. How tools related to supply chain impact supply chain efficiency under mass customization
   - How inventories impact supply chain efficiency under mass customization
   - How distribution over distances impact supply chain efficiency under mass customization
   - How sales processing impact supply chain efficiency under mass customization
3. How mass customization is influencing downstream supply chain efficiency.

1.3 Research methodology

To address the research questions, three major automotive companies from Germany will be investigated. Although the analysis could be carried out on more companies, however since mass customization is more practised by the German companies, moreover the laws and circumstances faced by the companies are much similar, therefore the studies is limited to only German companies. Three cases (Mercedes-Benz, BMW AG and Volkswagen AG) are evaluated with the mixed method approach, i.e. both qualitative and quantitative analysis. In qualitative analysis, case studies will be carried out while in the quantitative analysis would be based on Panel data analysis. Moreover, as discussed in section 1.2, the main research question is addressed via three sub questions; all these three questions are addressed via different methodology. As shown in Figure 1-2, issues related to efficient supply chain practices are addressed with qualitative analysis, in which the case study would be done on polices, practices and consequences, while supply chain management tools and issues in downstream supply chain will be addressed via quantitative analysis.

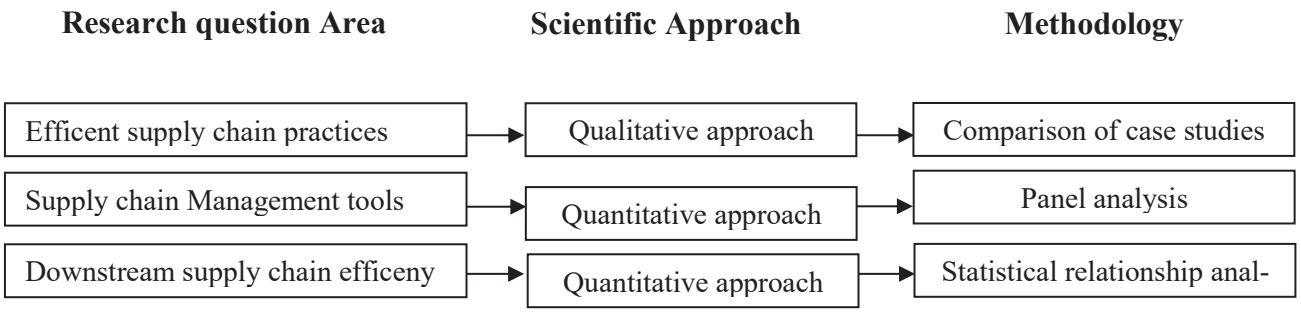

Figure 1-2: Research question and scientific approach link

1.4 Outline of the structure of the thesis

The study is divided into six chapters; chapter 2 discusses literature review about the basic concepts of supply chain under mass customization its, its evolution with the time, risks in modern practices and the studies related to the issue. In chapter three, first research question would be addressed using qualitative analysis of case studies of three German automotive companies; this analysis would be based upon the literature from scientific paper, automotive news, reports of companies and international surveys. Chapter fourth addresses second research question using quantitative analysis, econometric techniques of panel data analysis will be used in this section. Chapter 5 addresses research third question with some statistical techniques and data, the content of this chapter has already been published in a scientific paper. Each chapter of analysis will be followed by some results, at the end of the chapter. Based on these results, chapter 6 will address conclusion. Structure of studies is described in detail in the Figure 1-3.

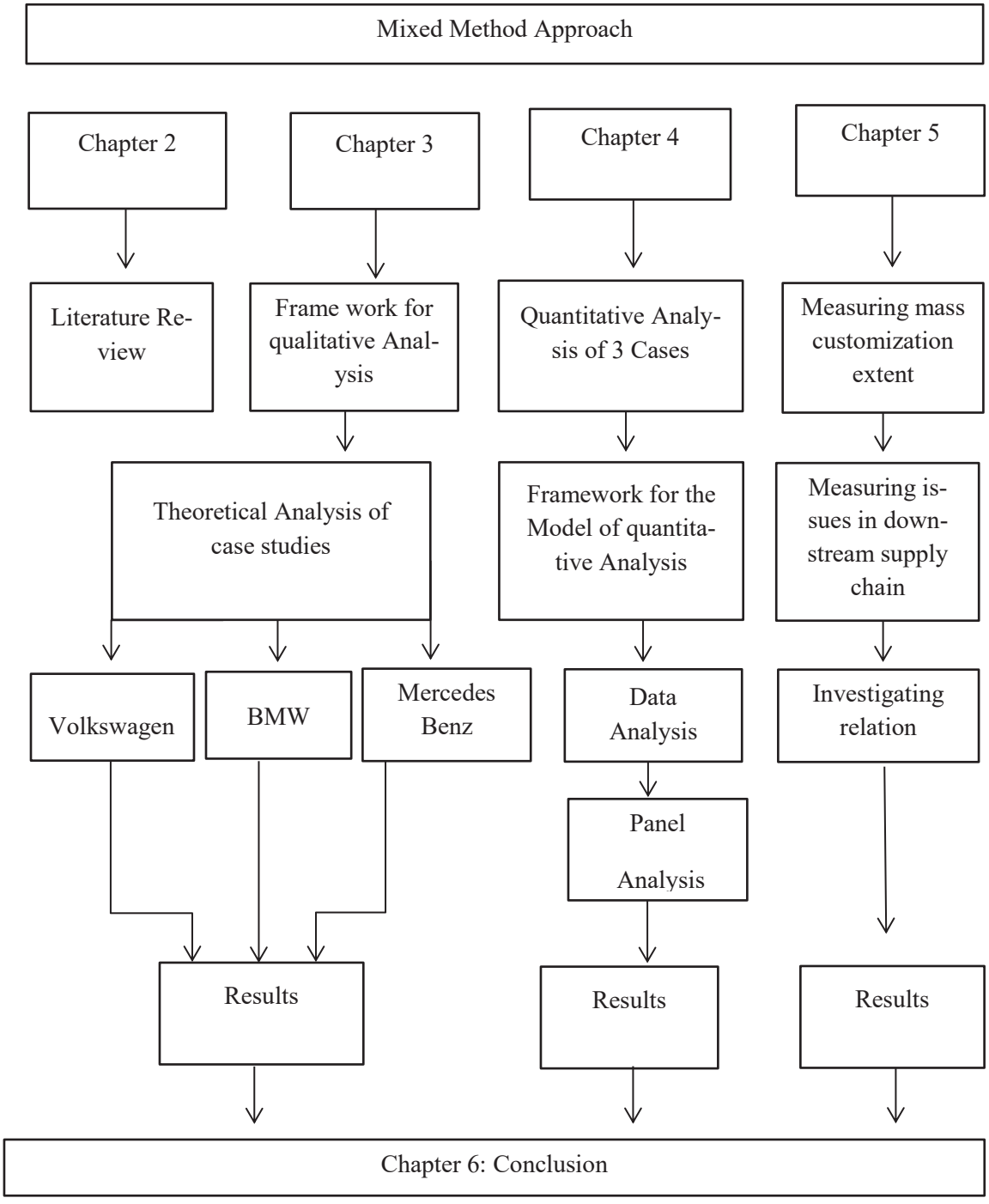

Figure 1-3: Structure of studies

1.5 Research significance

As the study would investigate different supply chain practices, it would able to investigate the most efficient supply chain practices under uncertain environment of mass customization; the study would help to investigate the potential risks and will help to devise the policy for risks managements. The

comparison among the companies cannot only impact the existing companies but would able be beneficial for the new starters. The study would also be important for the supplier, to manage their relationships in the uncertain environment. The study is highly related to the modern subject matter.

2 Literature review

2.1 Introduction

In this chapter, literature regarding supply chain management under mass customization, specifically for the automotive industry is analysed. To make the analysis structural, the chapter is divided into parts, as shown in Figure 2-1. In the first part, basic concepts related to this topic are explored, the second part considers how the concept of supply chain management and mass customization has evolved throughout the history of automotive industry, and the third part will analyse modern supply chain structure under mass customization, the risks associated with it, the literature regarding this and the research gap.

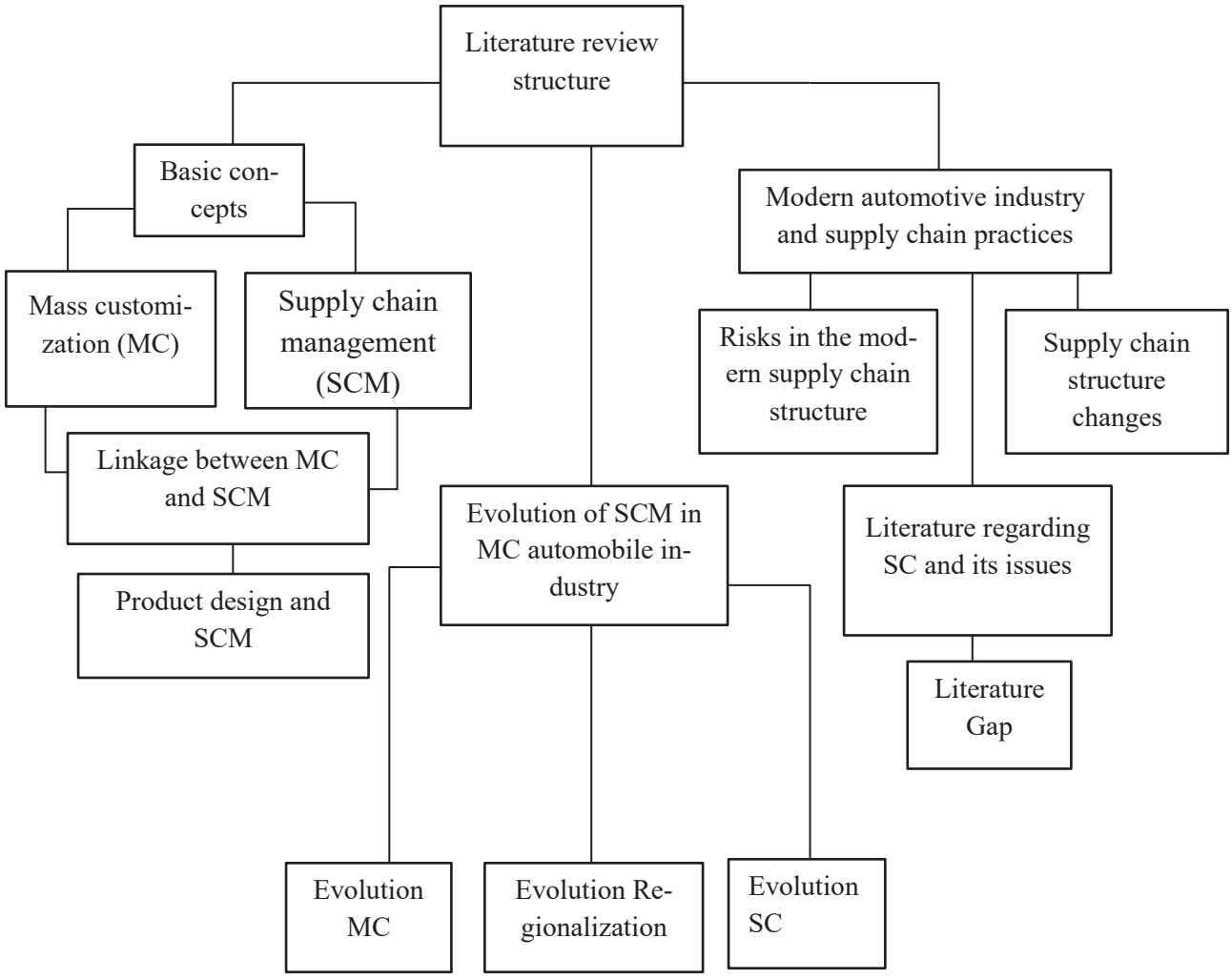

Figure 2-1: Structure of chapter 2

2.2 Basic concepts

2.2.1 Mass customization

The concept of mass customization in academia aroused as early as 1989. Earlier literature defined mass customization as a phenomenon where "the same large number of customers can be reached as in mass markets of the industrial economy, and simultaneously treated individually as in the customized markets of pre-industrial economies"[31]. This concept was further elaborated in 1993 with the reformed definition, which states mass customization as "providing tremendous variety and individual customization, at prices comparable to standard goods and service, to enable the production of products and services with enough variety and customization that nearly everyone finds exactly what they want"[32]. A more advanced definition was formed in 2001, as "the technologies and systems to deliver goods and services that meet individual customers' needs with near mass production efficiency"[33].

Although, mass customization carries characteristics from mass production and pure customization it is different from both of these concepts. Mass production is based on the concept that low varieties yield low cost of production while the concept of pure customization is vice-versa as shown in Figure 2-2. Mass customization, on the other hand, focuses on low cost customized products, which offers the best of both customization and mass production. Mass customization jointly utilizes the usefulness of mass production and individualization; as a result, this system has economies of scale and individualization as well[34]. This system is based on the logic that not only the choices among the customers are different, and can be satisfied with some group of choices. This has lead to the drastic decrease in the cost of production for customized products[35].

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[31]Davis, S. M. (1989). From "future perfect": Mass customizing. Planning review, 17(2), 16-21.
[32]Pine II, B. J., & Hull, R. (1995). Mass customization: the new frontier in business competition (Vol. 288). Harvard Business School Press.
[33]Tseng, M. M., & Jiao, J. (2001). Mass customization.Handbook of industrial engineering, 3, 684-709.
[34] Haasis, H. D. (2005). Mass customization in international logistics. Mass Customization. Concepts–Tools–Realization. Berlin, 189-193.
[35]Svensson, C., & Barfod, A. (2002). Limits and opportunities in mass customization for "build to order" SMEs. Computers in industry, 49(1), 77-89.

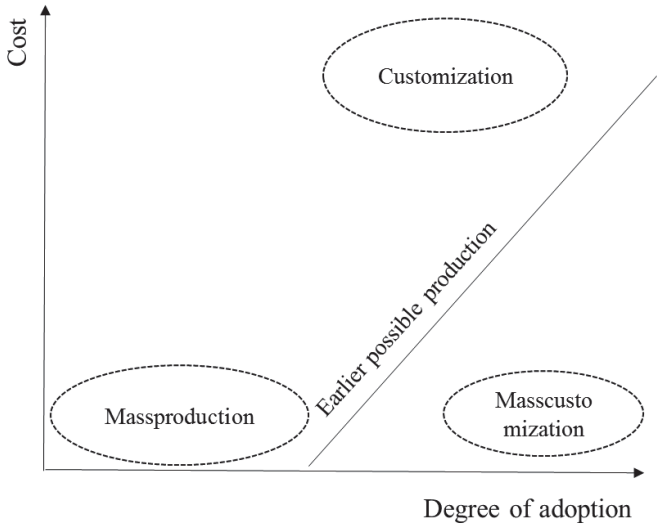

Figure 2-2: Difference between mass production and mass customization
Source: Svensson, C., & Barfod, A. (2002)[36]

There is a difference between just increase in product variety and mass customization. It is observed that in Automotive industry in US there was only increase in product variety while in Europe the high product variety is with mass customization[37]. Increasing product variety in a product category refers to increase in number of options in that category using traditional production methods[38], while mass customization as discussed above refers to adopting high number of option options concerning customer choices. The process of mass customization links with Build to order production, where the final production takes place after the order arrives.

An elaborated scientific study raises a question, "why mass customization is not there" to explain the concept of mass customization. It concluded that mass customization is a vision that leads companies to perform in a customer centric approach, which results in production of the products that are according to individual customer choice, and needs; this process is without surpluses that are characteristic

[36] Svensson, C., & Barfod, A. (2002). Limits and opportunities in mass customization for "build to order" SMEs. Computers in industry, 49(1), 77-89.
[37] Holweg, M. (2008).The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33.
[38]https://www.ukessays.com/essays/marketing/increasing-the-product-variety-in-a-product-category-marketing-essay.php Seen on Feb. 2019

of pure customization. While in the modern era, this term is used to describe all the strategies, which are connected with high variety, flexibility and personalization[39].

It is interesting to note that the concept has evolved during the last decade; in 1980s mass customization was mainly related to production in the context of flexible machinery and integration of computer related manufacturing, offering high variety[40]. The offerings were mainly in a retail environment and worked offline. It was not successful in most of the markets[41].

In 1998-2002, the concept of mass customization was more perceived as a way of customer interaction[42], this idea did not succeeded, as the customer value was not given importance[43]. In the recent times, mass customization has evolved as a way to improve mass production. The focus has shifted to a performance of the company in a customer centric manner, thus maintaining production according to customer need and desire, and at the same time not increasing which has led to a potential to improve business on a large scale[44].

The definition of mass customization has thus evolved with the time and led to the modern era definition of mass customization states it as "the ability to manufacture a relatively high volume of product options for a relatively large market that demands customization, without substantial trade-offs in cost,

[39]Piller, F. T. (2004). Mass customization: reflections on the state of the concept. International journal of flexible manufacturing systems, 16(4), 313-334.; Piller, F. (2003). Von open source zu open innovation. Harvard Business Manager, 25(12), 114.

[40]Piller, F. T. (2004). Mass customization: reflections on the state of the concept. International journal of flexible manufacturing systems, 16(4), 313-334.

[41]Piller, Salvador & Walcher (2013). The Market for Mass Customization Today. Enabling factors http://www.innovationmanagement.se/2012/04/16/part-2-the-market-for-mass-customization-today/ Seen on April 2014

[42]Piller, salvador&Walcher (2013). The Market for Mass Customization Today. Enabling factors http://www.innovationmanagement.se/2012/04/16/part-2-the-market-for-mass-customization-today/ Seen on April 2014

[43]Piller, F. T. (2004). Mass customization: reflections on the state of the concept. International journal of flexible manufacturing systems, 16(4), 313-334.

[44]Piller, F., (2005) Innovation and Value Co-Creation, II CP Press, Hong Kong and Munich.

delivery, and quality"[45]. Thus, it can be regarded as a production process which targets to meet individual customer demand with minimal loss of efficiency[46]. In other words meeting individual consumer demands while maintaining the efficiencies of a mass production system[47].

2.2.2 Supply chain management

Supply chain is defined vastly in literature; different studies have described it with different prospective. Supply chain management can be stated as the group of firms, which collaborate to take advantage of the strategic position and to improve overall efficiency. This includes collaborating with other firms in the chain of relationships, which benefits the customers too[48]. Broadly, all the studies describe it as all the processes and practices that are involved in efficient transfer of information and flow of materials between company, its suppliers and customers.

One of the studies gives a detailed description of the importance of supply chain in the modern world[49]. It establishes that with the advancement in technology, supply chain has become more direct, as modern business competition requires greater coordination in the supply chain networks of customers, producers and suppliers. Since the competition is fierce, so it is not on the level of firms, instead it is on the level of supply chain. Therefore, in modern times, supply chain competes with the supply chain. Modern businesses demand that supply chain should be prepared for any kind of challenges as any problems in supply chain can lead to decreasing profits, high inventory cost or poor return on assets. Moreover, for any kind of change in the business structure, supply chain should be moulded accordingly[50]. A typical supply chain structure for an automotive company is shown in Figure 2-3. Flow of product is from manufacturer to the customer and the flow of demand is in opposite direction towards the supplier. In a typical automotive supply chain manufacturer is regarded as a final assembler who is

[45]Liu, G., & Deitz, G. D. (2011). Linking supply chain management with mass customization capability. International Journal of Physical Distribution & Logistics Management, 41(7), 668-683.; McCarthy, I.P. (2004), "Special issue editorial: the what, why and how of mass customization", Production Planning & Control, Vol. 15 No. 4, pp. 347-51.

[46]Liu,G., & Deitz,G.D. (2011). Linking supply chain management with mass customization capability. International Journal of Physical Distribution & Logistics Management, Vol. 41 Iss: 7 pp. 668 – 683.

[47]Tseng, M. M., & Jiao, J. (2001). Mass customization. Handbook of industrial engineering, 3, 684-709.

[48]Foster, S. T. (2008). Towards an understanding of supply chain quality management. Journal of operations management, 26(4), 461-467. , Bowersox, D. J., Closs, D. J., & Cooper, M. B. (2007). Supply chain logistics management (Vol. 2). New York, NY: McGraw-Hill.

[49] Christopher, M. (2016). Logistics & supply chain management. Pearson UK.

[50]Christopher, M. (2016). Logistics & supply chain management. Pearson UK.

linked with Tier 1 suppliers; interior and power train supplier , tier 1 suppliers have the major contribution in creation of the value chain. These tier 1 suppliers are linked with few tier 2 suppliers, who manufacture different parts like engine, dashboards, doors etc. Tier 2 suppliers are connected with number of raw material suppliers. After manufacture, the car is transferred to the customers via different car dealers[51].

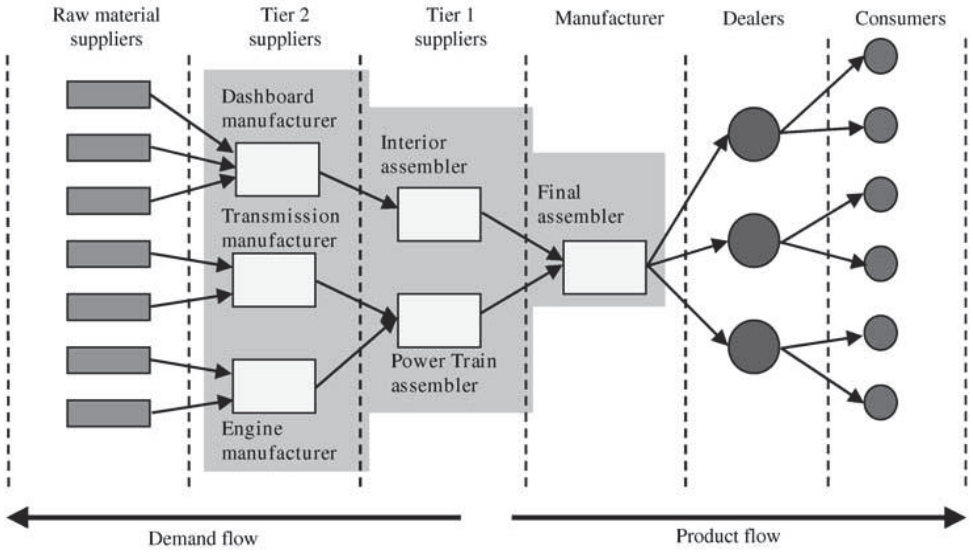

Figure 2-3: Typical automotive supply chain structure
Source: Chandra, C., & Kamrani, A. K. (2003)[52]

2.2.3 Interdependence of mass customization and supply chain management

There are enormous challenges to manage the supply chain of customized products; however, the nature of this system shows that there are not only enormous challenges but also enormous opportunities. As when the demand is unpredictable, like in the case of mass customization, supply and demand uncertainties can be used as tools to develop the right supply chain[53].

Literature shows the strong dependence of mass customization on supply chain. As research suggests that it is very important that there is well-organized communication, coordination between supplier and

[51] Chandra, C., & Kamrani, A. K. (2003). Knowledge management for consumer-focused product design. Journal of intelligent manufacturing, 14(6), 557-580.
[52] Chandra, C., & Kamrani, A. K. (2003). Knowledge management for consumer-focused product design. Journal of intelligent manufacturing, 14(6), 557-580.
[53] Lee, H. L. (2002). Aligning supply chain strategies with product uncertainties. California management review, 44(3), 105-119

producer is rapid, and a logistic system is very well integrated for the efficient mass customization[54]. One of the studies explains that inefficient supply chain management is the most important reason behind the failure of mass customization. It concluded that the tasks in mass customization are no longer repetitive, rather they become more complex and need to be flexible[55]. Moreover, it has also been found that many characteristics of mass customization such as high product variety, short product life cycle, increased out-sourcing and high dependence on information technology has a trend to make supply chain challenging and complex[56]. In other words, the characteristics of mass customization require that the manufacturer should effectively manage the supply chain[57]. Thus, if the company's relations with its suppliers and customers are managed efficiently and the information flows along the supply chain, then mass customization can give fruitful results[58]. Furthermore, there is also evidence of a correlation between mass customization capability and supplier lead-time reduction[59]. Therefore, sustainable competitiveness in modern production is only possible via development of customer responsive efficient supply chains, which help to perform operations globally[60].

Moreover, literature also shows that there is interdependence between supply chain quality and mass customization. A study carried out on 317 firms (from three industries) from ten different countries suggest that product modularity, cross function coordination and supply chain management contributes to increasing the capacity for mass customization[61]. An extension of this study suggested that quality

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[54] Berman, B. (2002). Should your firm adopt a mass customization strategy?. Business Horizons, 45(4), 51-60.

[55]Liu, G., &Deitz, G. D. (2011). Linking supply chain management with mass customization capability.International Journal of Physical Distribution & Logistics Management, 41(7), 668-683. ; Pine, B.J. (1993), Mass Customization: The New Frontier in Business Competition, Harvard Business School Press, Cambridge, MA.

[56] Lee, H. L. (2002). Aligning supply chain strategies with product uncertainties. California management review, 44(3), 105-119.

[57]Liu, G., & Deitz, G. D. (2011). Linking supply chain management with mass customization capability.International Journal of Physical Distribution & Logistics Management, 41(7), 668-683.; Duguay, C.R., Landry, S. and Pasin, F. (1997), "From mass production to flexible/agile production",International Journal of Operations & Production Management, Vol. 17 Nos 11/12, pp. 1183-95 ; Magretta, J. (1998), "The power of virtual integration: an interview with Dell Computer's Michael Dell", Harvard Business Review, Vol. 76 No. 2, pp. 72-84

[58]Liu, G., & Deitz, G. D. (2011). Linking supply chain management with mass customization capability.International Journal of Physical Distribution & Logistics Management, 41(7), 668-683

[59]Liu, G., & Deitz, G. D. (2011). Linking supply chain management with mass customization capability. International Journal of Physical Distribution & Logistics Management, 41(7), 668-683 ; Da Silveira, G., Borenstein, D., & Fogliatto, F. S. (2001). Mass customization: Literature review and research directions. International journal of production economics, 72(1), 1-13.

[60]Holweg, M. (2008). The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33.

[61] Zhang, M., Zhao, X., & Qi, Y. (2014). The effects of organizational flatness, coordination, and product modularity on mass customization capability. International Journal of Production Economics, 158, 145-155.

management of supply chain has also advanced with the increase in mass customization. The results obtained suggested that mass customization has increased the internal quality integration, while modularity in the production increases supplier quality integration. It was also found that supplier quality integration enhances the competitive performance of the firm[62]. These two studies thus show the interdependent link. The factors which increase the Mass customization capability (MCC) are also the factors that increase the supply chain quality thus mass customization capability and supply chain quality exhibits an interdependent relationship as shown in Figure 2-4.

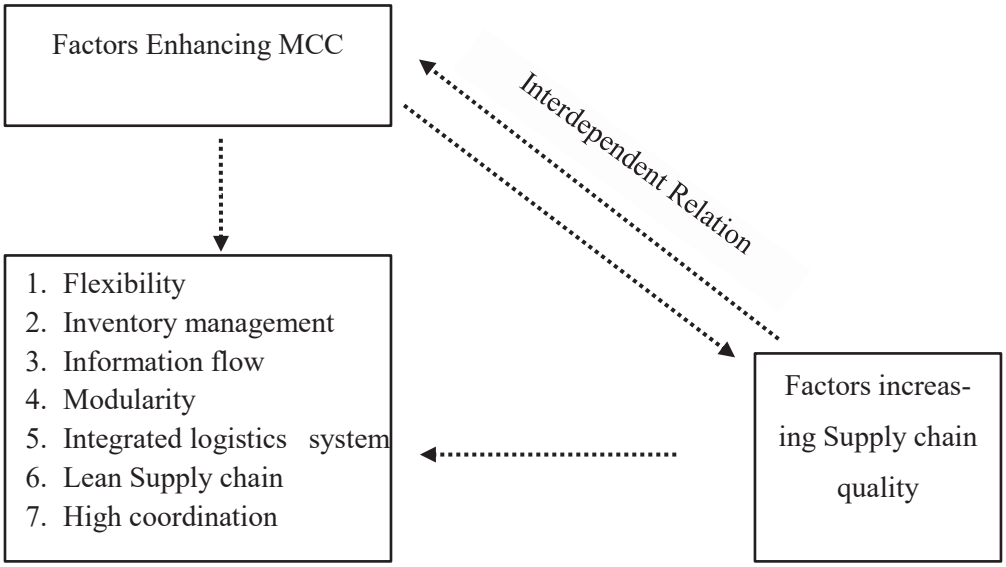

Figure 2-4: Inter linked relations

2.2.4 Product design and supply chain management

The concept of mass customization revolves around a dynamic product design, with the product design having a significant impact on the supply chain management[63]. The interrelation between product, pro-

[62]Zhang, M., Guo, H., Huo, B., Zhao, X., & Huang, J. (2017). Linking supply chain quality integration with mass customization and product modularity. International Journal of Production Economics.

[63] https://supplychainlogistics.wordpress.com/2011/07/23/product-design-and-supply-chain/ Seen on March 2017

duction and inter-firm leads to the development of a complete system where different entities are dependent upon one another[64]. Meanwhile the product architecture assessment is a tool to link product, process and decisions of supply chain design.[65] . Studies suggest that uncertainties in the supply chain can be reduced if the collaboration about the product design is the characteristic of the supply chain[66].

In the case of the automotive industry, assembling automobiles comprises a combination of different steps, sub assembling of modules, components and piece parts. The entire production of an automobile can be portioned to an assembling firm, first tier supplier and second tier supplier[67]. The differences in product architecture exist in different regions; European and United States (US) automakers tend to depend upon large subassemblies and used to outsource these subassemblies, while the Japanese automaker mostly focused on integral product architecture thus limiting the use of large sub-assemblies[68]. These differences in product and production architecture affect the flow of supply chain, we will analyse in the next section how production architecture, mass customization practices and supply change dynamics have evolved with time.

2.3 Supply chain and mass customization evolution in automotive industry

This section will explore the literature to investigate the evolution of dynamics of supply chain and mass customization, specifically with reference to the automotive industry. This section will form the basis for the analysis of the modern automotive industry.

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[64]Takeishi, A., & Fujimoto, T. (2001). Modularization in the auto industry: interlinked multiple hierarchies of product, production and supplier systems. International Journal of Automotive Technology and Management, 1(4), 379-396.

[65]Fixson, S. K. (2005). Product architecture assessment: a tool to link product, process, and supply chain design decisions. Journal of operations management, 23(3), 345-369.

[66]Lee, H. L. (2002). Aligning supply chain strategies with product uncertainties. California management review, 44(3), 105-119.

[67]Matsuo, H. (2015). Implications of the Tohoku earthquake for Toyota′ s coordination mechanism: Supply chain disruption of automotive semiconductors. International Journal of Production Economics, 161, 217-227.; Fujimoto, T. (1999). The evolution of a manufacturing system at Toyota, Oxford university press.

[68]Matsuo, H. (2015). Implications of the Tohoku earthquake for Toyota′ s coordination mechanism: Supply chain disruption of automotive semiconductors. International Journal of Production Economics, 161, 217-227 ; Takeishi, A., & Fujimoto, T. (2001). Modularization in the auto industry: interlinked multiple hierarchies of product, production and supplier systems. International Journal of Automotive Technology and Management, 1(4), 379-396.

2.3.1 Evolution in mass customization

Mass customization is not a new phenomenon in the automotive industry. Before the shift towards the mass production system, craft producers such as Hispano Suzia, Duesenberg and Panhardet employed skilled labour to handcraft vehicles. The basic theme was that many skilled labour forces handcrafted a single vehicle at one time, according to the customers' priority. This vehicle was expensive and could only be afforded by elites[69].

In 1913, Ford came up with the new idea, which focused on decreasing cost and increasing volumes. He proposed mass production against craft productions. However, this notion was not cost efficient without the idea proposed by Eli Whitney, to carry out mass production with standardized parts, which would enable inter changeability. This concept was driven from the arms making sector. The idea of standardized parts meant that the assembly operations could be streamlined; the concept was first implemented in the Highland Park factory of Ford with a moving assembly line. This vision of Henry Ford was a great success for nearly two decades, with the labour cost reduced from 750 hours per vehicle in 1913 to 93 hours in 1914. So within one year there was a sharp decline in the cost of production, allowing car prices to also sharply decline, meaning it was not only for the elites anymore[70]. Ford enjoyed market shares through this model until 1926, when General Motors (GM) offered a model Cadillac, which offered customers the choices they desire, through a much broader product portfolio. It developed a more decentralized organization structure, which laid a foundation for modern mass customization in the automotive industry[71].

In the 1990s, different companies like Toyota pursued the goal of advancement in mass customization, but failed. Toyota retreated from its goal of making customized products in 1993, the major reason behind this was that the company did not understand that it had to make major changes in the organization supply chain before pursuing mass customization. The same was case for many other automobile companies[72].

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[69]Holweg, M. (2008). The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33.

[70]Holweg, M. (2008).The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33.; Hounshell, D. (1985). From the American system to mass production, 1800-1932: The development of manufacturing technology in the United States (No. 4). JHU Press.

[71] Holweg, M. (2008).The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33.

[72]Pine, B. J., Victor, B., & Boynton, A. C. (1993). Making mass customization work. Harvard business review, 71(5), 108-11.

With the beginning of the 21st century, American companies like Ford and GM remained more focused towards product variety, while German companies like Volkswagen AG and BMW AG, mostly trended towards mass customization[73]. It is worthy to note that it was the adopting of the lean production technique, which changed the phase of automotive production. Volvo and Renault are considered as early adopters of a BTO production technique, which links the mass production with the customer demand[74]. In modern times, mass customization has become an important implementation for automotive companies. All the major automotive companies allow their customer to configure their car through BTO, by which customers are given a wide range of individual options, thus enabling billions of different types of car to be built[75].

In short, history reveals that the automotive industry has seen different phases, from craft production to mass production, then lean production, and now a trend of diversification and mass customization.

2.3.2 Evolution in production regionalization

Different regions around the world experienced ups and downs in the car production market. In other words, this industry never saw a monopoly held by a single region for the long time. Although the USA, Europe and Japan are considered as the main competitors in this industry, but the markets in Asia are changing their phase of automotive production. Figure 2-5 shows the ups and downs of different regions at various times. It can be seen that not a single region enjoyed the monopoly for the long time. This is explained further in the sections below.

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[73] Holweg, M. (2008).The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33.

[74]Hertz, S. (2001). Dynamics of alliances in highly integrated supply chain networks. International Journal of Logistics, 4(2), 237-256.

[75] Boysen, N., Emde, S., Hoeck, M., &Kauderer, M. (2015). Part logistics in the automotive industry: Decision problems, literature review and research agenda. European Journal of Operational Research, 242(1), 107-120. ; Pil, F. K., &Holweg, M. (2004).Linking product variety to order-fulfillment strategies.Interfaces, 34(5), 394-403.

Figure 2-5: Regionalization in Automotive production
Source: Author

Phases in Europe: After the phase of Ford and General Motors (GM) there was a decline in car production in the US and Europe, due to the crises of world war. This was followed by the increasing competition from the producers of Japan in 1970s. Toyota offered customers better deals in terms of price and quality[76]. After 1970, the car producers in Europe and the US went through tough times, for more than three decades. It was observed that the automotive industry in the so-called established region of Europe was not giving profitable results. There are different reasons attributed towards this. The global car production rose with an average of 2% per year, which was not very encouraging[77]. There were five closures of car companies in Briton alone and large job cuts in companies like Volkswagen AG and Mercedes-Benz. However, it was seen that for every plant that was shut down in Europe there was a plant being built in Asia[78]. The major reason for this downfall in Europe and the

[76]Holweg, M. (2008).The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33.
[77]Holweg, M. (2008).The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33
[78]https://www.press.bmwgroup.com/global/article/detail/T0279390EN/bmw-group-annual-report-2017?language=en Seen on October 2017

US was the establishment of Lean supply chains by Toyota in Japan. Lean supply chains are focused on reducing wastes and costs as much as possible, through management of inventories and other costs[79]. The method not only focused on the choices offered to the customers, but also focused on the details of how to carry out production with innovation, management of inventories, involvement of customers, management of suppliers, maximize flow and meet customer requirements. Due to these fierce competitive forces, the automakers in Europe and the US could not rely on traditional production methods at the end of the 20th century and they moved towards more innovative approaches[80]. Moreover, with mass customization, high variety and more responsiveness companies started making changes in supplier selection, suppliers' priority, supplier parks, inventory management etc.

Phase in Japan: Japanese enjoyed a large comparative advantage until 1994, after which its comparative advantage shrunk due to the adoption of the same technique by the west. Thus, the lean production systems were accepted as best while the high changes in supply chain made the conditions better for western automakers again. Moreover, Japanese companies faced mismanagement at the end of last century; many companies except Toyota and Honda were bought by western automakers. Although many mergers were seen in western automotive companies as well, like Daimler AG and Mitsubishi, however the comparative advantage of the west showed the better figures. Therefore, with the crises in Japanese automotive companies and the adoption of lean production systems all over the world, the comparative advantage enjoyed by Japanese automakers reduced.

One of the parameters to investigate efficiency is hours/vehicle; as shown in Figure 2-6, that Japanese comparative advantage declined with the start of 21st century. As in 1994, hours/vehicle in Japan was the least and had a large difference from the European and US markets. In 1994 hours /vehicle were 16.5 in Japan, 25.3 in Europe and 21.9 in the US, while this difference was reduced in 2000, when hours/vehicle declined slightly for Japan but declined significantly for the US and Europe. In 2000, it was 16.6 in US, 21.3 in Europe and 12.3 in Japan[81].

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https://www.volkswagenag.com/en/InvestorRelations/news-and-publications/Annual_Reports.html Seen on October 2017

[79] https://blog.procurify.com/2014/04/22/agile-lean-supply-chain-management/ Seen on March 2016

[80] Pil, F. K., & Holweg, M. (2004). Linking product variety to order-fulfillment strategies. Interfaces, 34(5), 394-403.

[81] Holweg, M., & Pil, F. K. (2004). The second century: reconnecting customers and value chain through build-to-order; moving beyond mass and lean production in the auto industry. Chain through Build-to-Order, Moving beyond Mass and Lean Production in the Auto Industry, MIT Press, Boston MA.

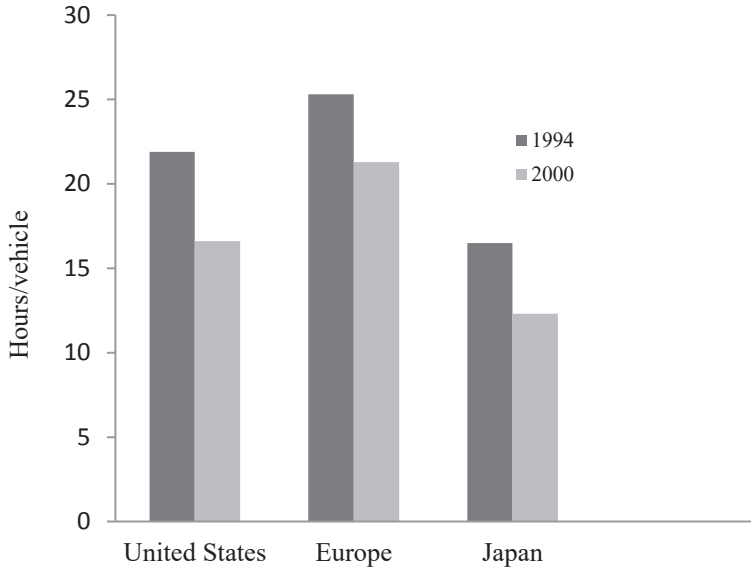

Figure 2-6: Comparative Advantage in different Regions
Source: Holweg M. and Pil F. (2004)[82]

Phase in Asia: The west, which once enjoyed the kingship in automotive industry, is not enjoying that position anymore. Emerging markets in Asia are grabbing the market share, so the picture of global shares is changing drastically. The high production growth in Asian regions have made Asian share in the output industry almost equivalent to Western Europe. The "China price" has become the reference price in the markets. Although this has shaken the western automakers, it should be noted that the western markets have also gained high benefits with low priced supplies[83].

The gain of market in Asia can also be analysed through statistical analysis; in 1970, Western Europe, the US and Japan accounted for 91% of global car production, while in 2004 these countries accounted for 70% of the share. Although in this period, the number of assembling plants in the world increased from 197 to 460, it is surprising to see that only 44 % of these plants were established in the markets of Western Europe, US and Japan, while the rest were in the emerging markets of Asia and South America[84]. The most emerging change that the automotive industry has faced is the entrance of China.

[82] Holweg, M., & Pil, F. K. (2004). The second century: reconnecting customers and value chain through build-to-order; moving beyond mass and lean production in the auto industry.
[83] Holweg, M. (2008).The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33.
[84]Holweg, M. (2008).The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33.

Statistics shows that in 1980 there was almost no car production in china, while in 2004 the country produced 2.32 million cars. Almost 90% of these cars were produced in joint venture plants in China. The literature suggests that what happened with the production in the automotive industry can be better stated as regionalism and not globalization[85].

2.3.3 Evolution in supply chains

In the end of the 1990s the automotive industry underwent large structural changes and many new concepts arose. Due to furious competition, automotive producers looked for dramatic changes in the supply chain. The structure of supply base was changed, new requirements for the suppliers were established and the suppliers with global sourcing were preferred more. In this section, we will elaborate these changes in detail.

2.3.3.1 **New approaches**

It is worthy to note, that when the automotive industry was undergoing dynamic changes and was moving towards more advanced approaches, two new approaches modularity and integrated supply become very popular[86]. These two approaches are based upon two different types of product architecture; modular architecture and integral architecture respectively. These architectures depend upon component standardization, product variety, product's change and product performance[87]. These two approaches have changed the preferences in the supply chain significantly. Below is the description of these two approaches.

Modularity

The process called Modularity usually supports high variety under mass customization. It is defined as "building a complex product or process from smaller subsystems that can be designed independently yet functions together as a whole" [88]. This concept was first introduced in automotive industry by Volkswagen AG and Mercedes-Benz, in 1996 and 1997 respectively. Under this process, individual

[85]Holweg, M. (2008).The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33.

[86]Collins, R., Bechler, K., & Pires, S. (1997). Outsourcing in the automotive industry: from JIT to modular consortia. European management journal, 15(5), 498-508.

[87] Matsuo, H. (2015). Implications of the Tohoku earthquake for Toyota′ s coordination mechanism: Supply chain disruption of automotive semiconductors. International Journal of Production Economics, 161, 217-227.

[88] Baldwin, C. Y., & Clark, K. B. (2003). Managing in an age of modularity. Managing in the modular age: Architectures, networks, and organizations, 149, 84-93.

components are delivered to final assembling line one by one, then the sub-assembling took place on the separate line, and then the module is transferred to the assembling line to be installed in vehicle[89]. It is studies that when an automotive company moves towards modular assembling, the traditional supply-side practices are not functional anymore. The supplier network and product structure become more complex, which changed supply chain relation as well[90]. The difference between modular supply chain and non-modular supply chain is shown in Figure 2-7.

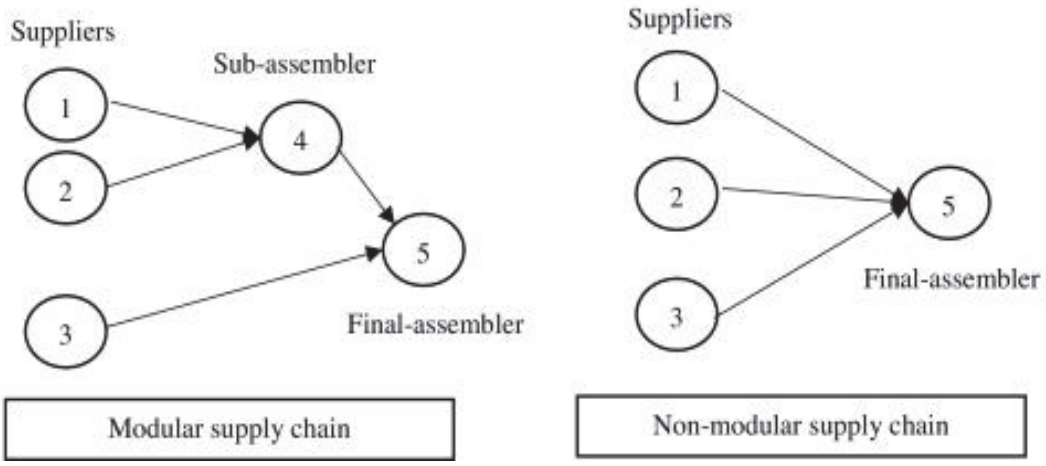

Figure 2-7: Difference between Modular supply chain and Non-modular supply chain
Source: Daie, P., & Li, S. (2016). [91]

Integrated Supply chain

Integrated supply chain consists of integration of functions, activities and system throughout in the supply chain. Under this system, supply chain is considered as an integrated business process, instead of individual systems or functions. All the entities in the supply chain are supposed to create value for each other; hence, the process is beyond the boundaries of the individual firm[92]. As shown in Figure 2-

[89] Reichhart, A., & Holweg, M. (2007). Do we still need supplier parks?. Automotive Logistics, 52-8.; Lin, Y., Shi, Y., & Ma, S. (2008). Supply-side collaboration with modular supply: cases from Chinese automotive industry. Mass Customization Services, 9.

[90] Lin, Y., Shi, Y., & Ma, S. (2008). Supply-side collaboration with modular supply: cases from Chinese automotive industry. Mass Customization Services, 9.

[91] Daie, P., & Li, S. (2016). Hierarchical clustering for structuring supply chain network in case of product variety. Journal of Manufacturing Systems, 38, 77-86.

[92] Vickery, S. K., Jayaram, J., Droge, C., & Calantone, R. (2003). The effects of an integrative supply chain strategy on customer service and financial performance: an analysis of direct versus indirect relationships. Journal of operations management, 21(5), 523-539.; Stevens, G. C. (1989). Integrating the supply chain. International Journal of physical distribution & Materials Management, 19(8), 3-8. ; Tan, K. C., Kannan, V. R., & Handfield, R. B. (1998). Supply chain management: supplier performance and firm performance. Journal of Supply Chain Management, 34(3), 2.

8, the process deals with integration in information, production flow and value creation between customer, distributor, producer and supplier.

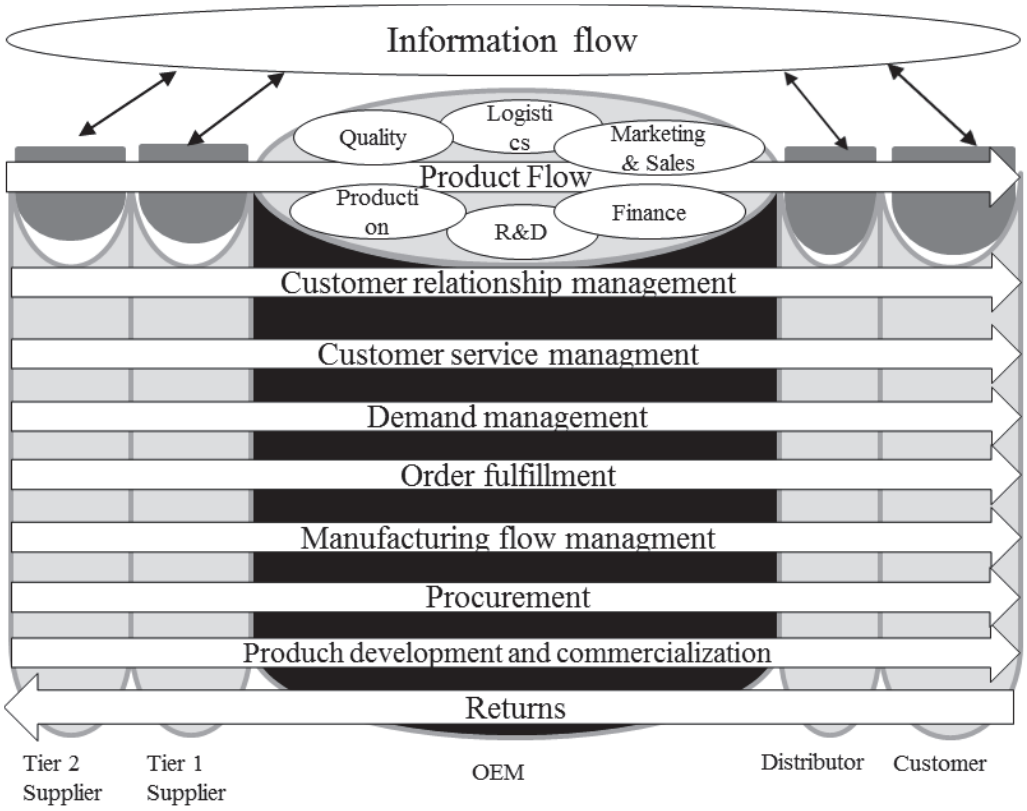

Figure 2-8: Integrated supply chain structure
Source: Lambert, D. M., Cooper, M. C., & Pagh, J. D. (1998)[93]

2.3.3.2 **Role of supplier**

With the progress in the above-mentioned approaches, the involvement of the supplier in the production has increased. The first-tier supplier has the responsibility of assembling the module while the second- and third-tier suppliers are supposed to provide parts[94]. A new approach, modular consortium, further expands this concept. In many cases, the first-tier supplier has the responsibility to assemble the module directly on the assembling line of the manufacturer. This concept was experimented first as early as the 1990s by Volkswagen AG and Skoda. It is based on long-term contractual relationships

[93] Lambert, D. M., Cooper, M. C., & Pagh, J. D. (1998). Supply chain management: implementation issues and research opportunities. The international journal of logistics management, 9(2), 1-20.
[94] Collins, R., Bechler, K., & Pires, S. (1997). Outsourcing in the automotive industry: from JIT to modular consortia. European management journal, 15(5), 498-508.

with a number of first-tier suppliers; therefore, the supplier has the greater responsibility of assembling of module, fitting that on to the vehicle, investment stake and the management of supply chain of the module. With this type of relationship with the supplier, the automotive company has less responsibility and has only to manage the plant and the final testing of the vehicles[95]. In the late 1990s, the concept was expanded to other automotive companies, as the Daimler AG factory in Hambach also started this approach and is still practising it now. In this case, the key subsystem suppliers participated directly in the production processes and were supposed to make direct investment in the factory area. They were allocated places to store inventory and in many cases were supposed to fit the article directly onto the vehicle. Such supplier's hubs were proved successful and reduced uncertainties in the supply line[96].

With the implementation of these new concepts, suppliers added the greater value in supply chain. Suppliers got more involved in the designing, part manufacturing and assembling than before. This new concept changed the shape of supply chain entirely. Before that suppliers and the assemblers may have been the different territories, but with this new concept implemented, suppliers preferred to move towards the manufacturers. One example of such collaboration can be seen in the production of the Mercedes-Benz smart car, where one of the suppliers of the car "Robert Bosch GmbH" has representation at production sites.

2.3.3.3 **Lean targets**

In the last decade, with the universal acceptance of lean production success, the targets of the OEMs changed in Europe and the United States. The Japanese model was implanted largely. Companies aimed to reduce inventory cost and were trying to relocate plants as close to the customer as possible. Moreover, the importance of logistics companies increased many folds and these companies took up many additional tasks related to value added services. In some cases, the logistics companies have the responsibility to sequence or configure the vehicle[97].

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[95]Pavlínek, P., & Janak, L. (2007). Regional restructuring of the Skoda Auto supplier network in the Czech Republic. European urban and regional studies, 14(2), 133-155.

[96] Lee, H. L. (2002). Aligning supply chain strategies with product uncertainties. California management review, 44(3), 105-119.

[97]Holweg, M. (2008).The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33. ; Reichhart, A., & Holweg, M. (2008). Co-located supplier clusters: forms, functions and theoretical perspectives. International Journal of Operations & Production Management, 28(1), 53-78.

2.4 Modern supply chain practices

The automotive industry is composed of physical distribution and supply chain management. The major components of automotive supply chain are tier 1-3 suppliers, distribution centers, logistics centers, dealers, OEMs and customers[98]. Automotive companies create only 30-35% of total value internally; the rest is attributed to the suppliers[99]. In the modern supply chain, automotive companies are purchasing entire subassemblies from the suppliers, like doors, power trains and electronics. The trend of outsourcing major subassemblies to the suppliers is increasing[100].

As discussed previously, the relationships in the automotive supply chain have undergone some major changes. Lean production methods, globalization and modularization have affected the relationship between suppliers and automotive manufacturers, specifically the first-tier suppliers[101]. To make sure that the assembling line is never short of parts, the greatest challenge for automakers under mass customization is managing supply chain. With the implementation of JIT and increased product variety, the challenge has high importance as thousands of parts and equipment, logistics workers and ware houses need to be connected[102]. To explain this challenging situation, in this section we will analyze the modern structural changes in supply chain after mass customization implementation, the risks associated with it and literature on the subject matter.

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[98] Ambe, I. M., & Badenhorst-Weiss, J. A. (2010). Strategic supply chain framework for the automotive industry. African Journal of Business Management, 4(10), 2110. ; Tang, D., & Qian, X. (2008). Product lifecycle management for automotive development focusing on supplier integration. Computers in industry, 59(2), 288-295.

[99] Ambe, I. M., & Badenhorst-Weiss, J. A. (2010). Strategic supply chain framework for the automotive industry. African Journal of Business Management, 4(10), 2110. ; Becker, W., & Dietz, J. (2004). R&D cooperation and innovation activities of firms—evidence for the German manufacturing industry. Research policy, 33(2), 209-223.

[100] Ambe, I. M., & Badenhorst-Weiss, J. A. (2010). Strategic supply chain framework for the automotive industry. African Journal of Business Management, 4(10), 2110. ; Benko C, McFarlan W (2004). Metamorphosis in the auto industry. Strategy and Leadership, 31 (4): 4-8.

[101] Morris, D., Donnelly, T., & Donnelly, T. (2004). Supplier parks in the automotive industry. Supply Chain Management: An International Journal, 9(2), 129-133.

[102] Boysen, N., Emde, S., Hoeck, M., & Kauderer, M. (2015). Part logistics in the automotive industry: Decision problems, literature review and research agenda. European Journal of Operational Research, 242(1), 107-120.

2.4.1 Change in structure of supply chain

The new wave of information technology in the automotive industry has changed the structure of supply chain completely[103]. In following the Japanese method of production, the western automotive companies also started relying on the few suppliers' approach, which has resulted in high dependence. With the establishment of lean production methods, companies now prefer to reduce inventory at each step, meanwhile there is a high trend of outsourcing, reducing the number of suppliers, and globally sourced components. Companies are focus on building a long-term strong partnership with few suppliers. Moreover, due to increasing product variety and customization options these suppliers are supposed to provide customized parts, therefore companies heavily rely on them[104]. We discuss now these changes in detail.

2.4.1.1 **Build to order**

The number of variants in the automotive industry are increasing, thus to meet the challenges of mass customization, automotive companies have established a production system, opposite to "Make to order" (MTO). Nowadays most of the cars produced in the automotive industry are customized under the business model "Build to order" or "Assemble-to-order. Under this system, automakers allow their customers to customize their car through a software program "Build your own car". Customers can use this software program and select from the number of options to develop a desired variant of the model, as shown in Figure 2-9.

[103]Auramo, J., Kauremaa, J., &Tanskanen, K. (2005). Benefits of IT in supply chain management: an explorative study of progressive companies. International Journal of Physical Distribution & Logistics Management, 35(2), 82-100.

[104]https://www.theguardian.com/business/2016/aug/23/vw-settles-dispute-which-stopped-output-at-half-of-german-plants Seen on Nov. 2016

Figure 2-9: Build your own car program
Source: Start from Scratch: Build Your Own Car Online[105]

This production system has been considered globally as a competitive one. However, automotive companies have to face the challenge of time management from order until delivery. This manufacturing system has two parts; push and pull. In the first step or push phase, different components and subassemblies are manufactured, mostly on forecast base. While in the second part or pull phase the products are assembled according to the customer's specification. The second phase has the tendency to cause delays[106]. However, it is observed that most customers are ready to accept delays for customized cars. This Build-to-order process has largely revolved around the internet-based e-procurement across the automotive industry. However, since the producer does not know about the coming order, the manufacturing model has lot of uncertainties[107]. The first company to implement BTO was Dell, while BMW AG was the first automobile company to allow customers to make changes to the car production even 6 days before assembly[108].

[105]https://www.autobytel.com/car-buying-tips/new-car-buying-tips/start-from-scratch-build-your-own-car-online-100379/ Seen on April 2014

[106] Leskova, A. (2012) Build-To-Order Principle Of Customized Production In The Field Of Automotive, Transfer inovacii

[107]Leskova, A. (2012) Build-To-Order Principle Of Customized Production In The Field Of Automotive, Transfer inovacii

[108]Lin, Y., Ma, S., & Zhou, L. (2012). Manufacturing strategies for time based competitive advantages. Industrial Management & Data Systems, 112(5), 729-747.

In order to meet the needs of BTO, companies have developed Build to order supply chain (BOSC), which are highly flexible and responsive. BOSC has several advantages; it increases responsiveness, flexibility and reduces cost. Since this system reduces the finished goods inventories, which have the highest value, thus the cost of inventories reduce significantly. BOSC has different requirements than normal conventional production methods but due to its high demand and benefits, several companies have successfully implemented it[109].

2.4.1.2 **Outsourcing**

In modern production systems, major subsystems are outsourced to the supplier. This trend is followed not only in the automotive industry but also in the aircraft industry. As previously, Boeing preferred to make major parts in-house, with the help of its own engineers, but now suppliers develop up to 70% of the latest Boeing 787s. This practice is also being followed in other industries, thus the burden on the OEMs is minimized[110]. It is a common perception that when a subsystem is outsourced, a modular product architecture is adopted, thus leading to the decline in technical coordination[111]. As outsourcing is supported by modular product design, which not only integrates innovation from the supplier but also helps to manage outsourcing efficiently, it has increased rapidly in last two decades[112].

2.4.1.3 **Modularization in automotive industry**

a. Basic concept

Modularization is a modern production phenomenon, which has become very popular in the German automotive industry. This production method is a powerful way to maintain efficiency in uncertain conditions, specifically under mass customization[113]. The concept of modularization in the automotive

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[109]Gunasekaran, A., &Ngai, E. W. (2005). Build-to-order supply chain management: a literature review and framework for development. Journal of operations management, 23(5), 423-451.

[110] Kotha, S., Olesen, D. G., Nolan, R., & Condit, P. M. (2005). Boeing 787: Dreamliner. Harvard Business School Case Study, 9-305. ; Ülkü, S., & Schmidt, G. M. (2011). Matching product architecture and supply chain configuration. Production and Operations Management, 20(1), 16-31. ; Christensen, C. M., M. E. Raynor. 2003. The Innovator's Solution: Creating and Sustaining Successful Growth. Harvard Business School Press, Boston, MA.

[111]Ülkü, S., & Schmidt, G. M. (2011). Matching product architecture and supply chain configuration. Production and Operations Management, 20(1), 16-31.; Christensen, C., & Raynor, M. (2013). The innovator's solution: Creating and sustaining successful growth. Harvard Business Review Press.

[112] A, Cabigiosu. et all (2013) Modularity, interfaces definition and the integration of external sources of innovation in the automotive industry.

[113]Baldwin, C., & Clark, K. (2006).Modularity in the design of complex engineering systems. Complex engineered systems, 175-205.

industry means that modules are assembled, with the large number of components, off the assembling lines (according to customer preferences). These modules are then transported onto production lines to be incorporated into the main structure[114]. In the modern automotive industry, the suppliers prepare these modules, thus the first-tier suppliers have become the module suppliers[115]. Figure 2-10, shows the concept of modularity in the automotive industry.

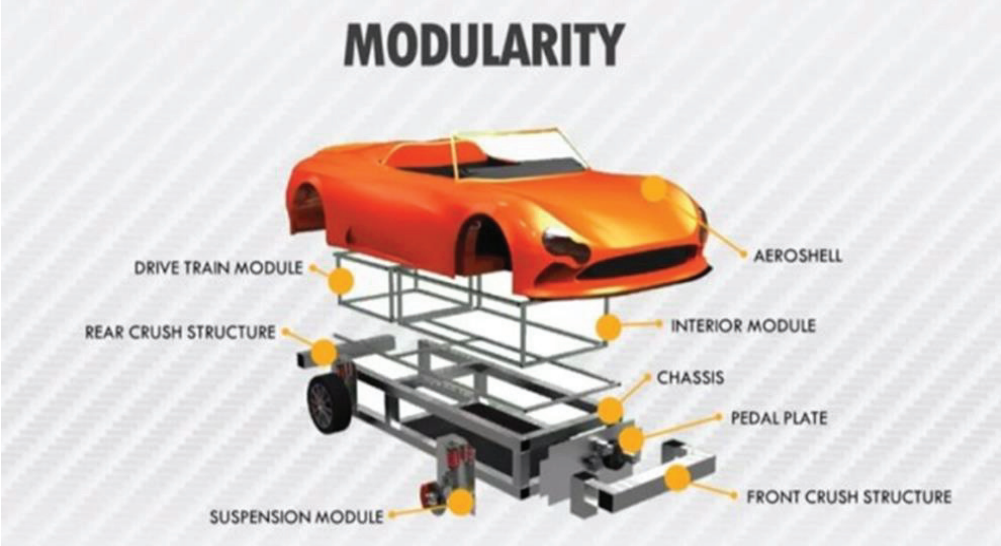

Figure 2-10: Modularization in production
Source: Benjamin Tincq (2012)[116]

b. Modular Platform

To maintain efficiency while pursuing modularization, automotive companies use a common platform for the standardization of car modules. With the new approach of modular platforms, even models from different brands can be made on the same platform, thus enabling efficiency and higher variety. This allows millions of variants of automotive to be produced at the same manufacturing facility in the plant

[114] Pandremenos, J., Paralikas, J., Salonitis, K., & Chryssolouris, G. (2009). Modularity concepts for the automotive industry: a critical review. CIRP Journal of Manufacturing Science and Technology, 1(3), 148-152.; Sako, M., & Murray, F. (1999). Modules in design, production and use: implications for the global auto industry. In IMVP Annual Sponsors Meeting.
[115] Collins, R., Bechler, K., & Pires, S. (1997). Outsourcing in the automotive industry: from JIT to modular consortia. European management journal, 15(5), 498-508.
[116] Benjamin Tincq (2012), Ouishare Magazine, http://magazine.ouishare.net/2012/10/wikispeed-agile-manufacturing/

[117]. Therefore, this production system decreases the complexity in the process and at the same time leads to an increase in product variety. It is the key way to achieve mass customization. Moreover, literature shows that flexibility in processing modular production and supply chain integration lead to efficient supply chain management[118].

c. Supply side collaboration

Supply side collaboration under modularization is mainly of two types, partially integrated module and fully integrated module. The main difference between the two systems is the role played by the Third party Logistics provider (3PL)[119]. Two cases of automotive air conditioners are analysed in this section, one is manufactured through fully integrated module while the other is developed via partial integrated module.

I Fully integrated Module

Under Fully integrated module system the major key players are automotive suppliers and module suppliers. However, the module supplier has a complex supply chain as it is connected to the different components suppliers. The module suppliers are mostly located near the automotive assembling plants and provide JIT delivery to the automakers[120]. This system is shown in Figure 2-11.

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[117]Leskova, A. (2012) Build-To-Order Principle Of Customized Production In The Field Of Automotive, Transfer inovacii ; Oughton, D. (2007) Automotive Supply Base Roadmap. Report of a workshop facilitated by Institute for Manufacturing, University of Cambridge. http://www.ifm.eng.cam.ac.uk/upload s/Research h/CTM/Roadmapping/auto_supply_roadmap_re port.pdf Seen on Nov. 2018

[118]Fogliatto, F. S., Da Silveira, G. J., &Borenstein, D. (2012). The mass customization decade: An updated review of the literature. International Journal of Production Economics, 138(1), 14-25.; Salvador, F., De Holan, P. M., & Piller, F. (2009). Cracking the code of mass customization. MIT Sloan management review, 50(3), 71-78.

[119] Lin, Y., Shi, Y., & Ma, S. (2008). Supply-side collaboration with modular supply: cases from Chinese automotive industry. Mass Customization Services, 9.

[120] Lin, Y., Shi, Y., & Ma, S. (2008). Supply-side collaboration with modular supply: cases from Chinese automotive industry. Mass Customization Services, 9.

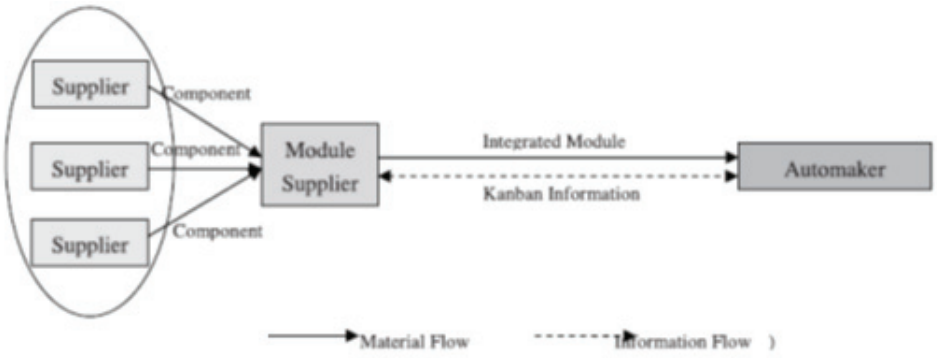

Figure 2-11: Fully integrated module supply chain
Source: Lin, Y., Shi, Y., & Ma, S. (2008)[121]

The information and production flow under this system are not very complex, automotive company discuss their production plan and related information with the module supplier, hence module supplier can establish their information flow with the component suppliers. The fully integrated module is supplied directly to the automaker. Information flow from the automotive company to the module supplier is through the Kanban system, the order is received at least two hours ahead to the module supplier[122]. Figure 2-12 shows the information and production flow under this system.

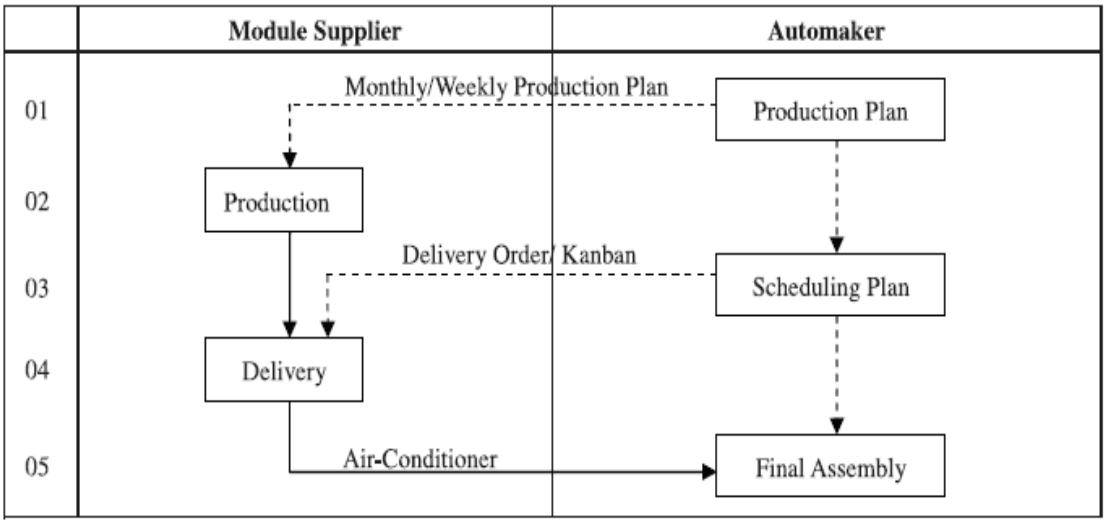

Figure 2-12: Information and product flow under FIM
Source: Lin, Y., Shi, Y., & Ma, S. (2008)[123]

[121] Lin, Y., Shi, Y., & Ma, S. (2008). Supply-side collaboration with modular supply: cases from Chinese automotive industry. Mass Customization Services, 9.
[122] Lin, Y., Shi, Y., & Ma, S. (2008). Supply-side collaboration with modular supply: cases from Chinese automotive industry. Mass Customization Services, 9.
[123] Lin, Y., Shi, Y., & Ma, S. (2008). Supply-side collaboration with modular supply: cases from Chinese automotive industry. Mass Customization Services, 9.

II Partially integrated module

An example of partially integrated module (PIM) is shown in Figure 2-13, which shows supply chain of auto motive's company air conditioner. Here the First tier suppliers are providing components to the 3PL, who manufacture the module and transfer it directly to the manufacturer. 3PL provider thus provides logistics as well production function (sub-assembly). This system requires close collaboration between different entities, to ensure efficient in-bound logistics operations[124].

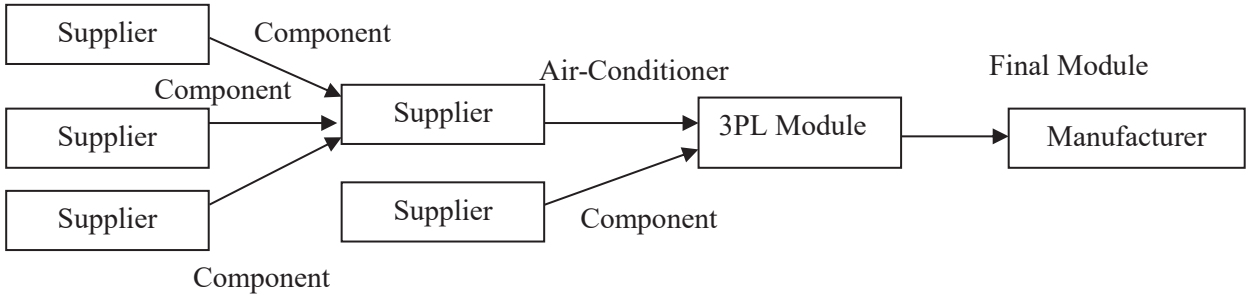

Figure 2-13: Partially integrated modularization
Source: Lin, Y., Shi, Y., & Ma, S. (2008)[125]

The production and information flow in this system is shown in Figure 2-14, under this system even the low value components being provided to 3PL provider needs to be managed very efficiently. Mostly the components supplier receives the order directly from the 3PL provider instead of manufacturer. This information system needs a regulated information flow between PIM supplier, 3PL provider, and component supplier[126].

[124] Lin, Y., Shi, Y., & Ma, S. (2008). Supply-side collaboration with modular supply: cases from Chinese automotive industry. Mass Customization Services, 9.
[125] Lin, Y., Shi, Y., & Ma, S. (2008). Supply-side collaboration with modular supply: cases from Chinese automotive industry. Mass Customization Services, 9.
[126] Lin, Y., Shi, Y., & Ma, S. (2008). Supply-side collaboration with modular supply: cases from Chinese automotive industry. Mass Customization Services, 9.

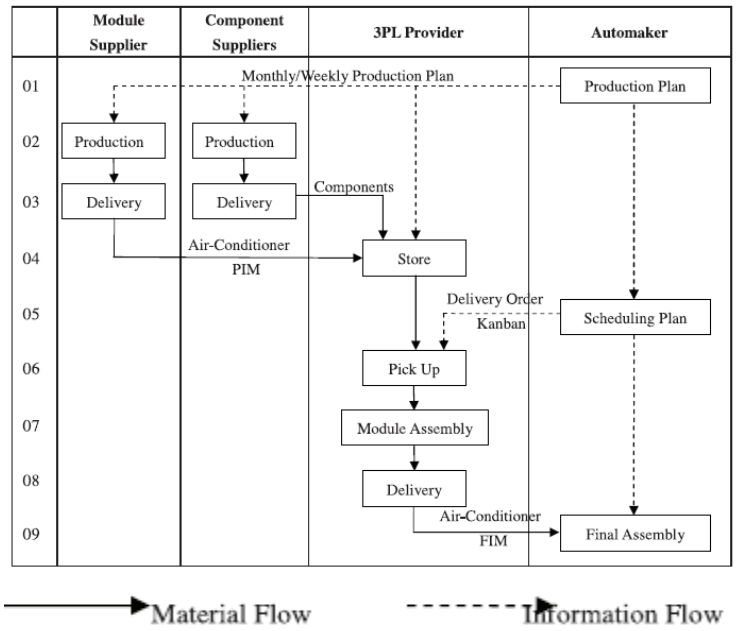

Figure 2-14: Information and production flow in PIM
Source: Lin, Y., Shi, Y., & Ma, S. (2008)[127]

2.4.1.4 **Supplier Parks**

Another important aspect seen in the automotive industry is the development of supplier parks. These supplier parks are common in Europe and Latin America. The larger global suppliers have resources to build such parks. Broadly, it is identified that there are three main reasons for such supplier parks: labour cost reduction, logistics cost reduction and increase efficiency. With the increase in technology, OEM considers the fact that it may not have all the resources to build modern automotive structures. While with the introduction of JIT, the parts were supposed to reach the OEM in a very short time, thus supplier parks were started being built in 1990s. These parks, stores different modules that could be provided for immediate assembly, in such parks, often-small tasks of sequencing and minor assembling were provided via logistics companies. As a result, the value-added services were withdrawn from the manufacturers towards the suppliers, and to some extent to the logistics companies[128].

[127] Lin, Y., Shi, Y., & Ma, S. (2008). Supply-side collaboration with modular supply: cases from Chinese automotive industry. Mass Customization Services, 9.

[128]Larsson, A. (2002). The development and regional significance of the automotive industry: supplier parks in Western Europe. International Journal of Urban and Regional Research, 26(4), 767-784.

2.4.2 Risk analysis of modern supply chain practices

With the increase in the globalization, the problems of supply chain have become more crucial. When the supply chain has global linkages, the traditional supply chain practices have limited impact[129]. This scenario has become more critical for the automotive industry, as the studies show that the modern automotive industry is already faced with high complexity and uncertainty, (mainly because of mass customization and high reliance on suppliers). Thus, it is very important for automotive companies to make their supply chains risk free and secure. In this line, the automotive companies have to care for not only big external risks but also small vulnerable internal risks[130]. In this section, we give a brief description of the risks faced by automotive industry in modern supply chains.

2.4.2.1 **Risks with JIT**

The automotive industry keeps up with the modern demands. However, the focus of the industry is towards the cost efficiency since 1990[131]. To meet the fierce competition, companies focus towards streamlining the supply chain through the Just in time and just in sequence techniques. The trends towards the just in time implementation resulted in low inventories, which makes supply chain vulnerable to shocks as the supply chain can barely compensate in the absence of the safety stocks level. However, high relations with the supplier, which makes OEM vulnerable to risks, follow the implementation of the technique especially in the short term[132].

[129]Zhang, M., Guo, H., Huo, B., Zhao, X., & Huang, J. (2017).Linking supply chain quality integration with mass customization and product modularity. International Journal of Production Economics. ; Flynn, B. B., & Zhao, X. (Eds.). (2014). Global supply chain quality management: Product recalls and their impact. CRC Press. Robinson, C. J., & Malhotra, M. K. (2005). Defining the concept of supply chain quality management and its relevance to academic and industrial practice. International Journal of Production Economics, 96(3), 315-337.

[130]Thun, J. H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. International Journal of Production Economics, 131(1), 242-249.

[131]Thun, J. H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. International Journal of Production Economics, 131(1), 242-249.; Lee, H. L. (2004). The triple-A supply chain. Harvard business review, 82(10), 102-113.

[132]Thun, J. H., &Hoenig, D. (2011).An empirical analysis of supply chain risk management in the German automotive industry. International Journal of Production Economics, 131(1), 242-249.; Childerhouse, P., Hermiz, R., Mason-Jones, R., Popp, A., & Towill, D. R. (2003). Information flow in automotive supply chains–present industrial practice. Industrial Management & Data Systems, 103(3), 137-149.

2.4.2.2 **Risks with globalization**

Modern production systems are very complex, which results in the high interfaces and makes supply chain vulnerable to risks[133]. Moreover, globalized supply chains are more vulnerable to risks due to globalization, increased risk in transportation, exchange rate and cultural aspects[134]. The examples of globalized supply chains suffering from the risks were observed when Toyota and Ford had to stop the production in the manufacturing plants after 9/11, as the parts delivery to the US plants was affected[135].

2.4.2.3 **Dependence on suppliers**

As discussed earlier, in modern production the automotive companies are relying on suppliers, however problems in supply chain can occur because of quality from the suppliers or any other kind of disruptions from the suppliers. For example: in 2001 production at Land Rover plant stopped because the supplier was the target of bankruptcy[136]. Another disruption of the supply chain occurred when a German supplier delivered the automotive companies defective pumps in 2005. Later a sub supplier was found accountable for this mistake but it had affected the whole supply chain (more such examples from high supplier reliance will be discussed in the next chapter). These examples show that the integration and dependencies of companies in the supply chain can lead to risks[137]. The supply chain dis-

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[133]Thun, J. H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. International Journal of Production Economics, 131(1), 242-249.; Peck, H. (2005). Drivers of supply chain vulnerability: an integrated framework. International journal of physical distribution & logistics management, 35(4), 210-232.

[134]Thun, J. H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. International Journal of Production Economics, 131(1), 242-249.; Barry, J. (2004). Supply chain risk in an uncertain global supply chain environment. International journal of physical distribution & logistics management, 34(9), 695-697.

[135]Sheffi, Y. (2001). Supply chain management under the threat of international terrorism. The International Journal of logistics management, 12(2), 1-11.

[136]Thun, J. H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. International Journal of Production Economics, 131(1), 242-249.; Sheffi, Y., & Rice Jr, J. B. (2005). A supply chain view of the resilient enterprise: an organization's ability to recover from disruption quickly can be improved by building redundancy and flexibility into its supply chain. While investing in redundancy represents a pure cost increase, investing in flexibility yields many additional benefits for day-to-day operations. MIT Sloan management review, 47(1), 41-49.

[137]Thun, J. H., &Hoenig, D. (2011).An empirical analysis of supply chain risk management in the German automotive industry. International Journal of Production Economics, 131(1), 242-249.

ruptions that resulted from high supply chain dependence have led to the negative impact on the companies. In some cases, high financial losses were incurred which even resulted in the exit of OEM, and such exits come after the sharp losses of almost $50-$100 million dollar per day[138].

2.4.2.4 **Risks in outsourcing and modularization**

Although modular production systems decrease the complexity and increase the variety in the production system, this production system could lead to some critical situations. One of the main reasons is that this strategy could have drastic effects on the supply chain, as the lead supplier's activities are extended, which implies that the activities of other suppliers are decreased. In other words, the monopoly or dependence on few suppliers increases. Meanwhile, the activities of OEM decrease and at the same time, they have to grip the control on the entire supply chain. This could lead to many supply chain issues, the attention of OEM shifts towards the supply chain relationships and controls[139]. Moreover, modularization has a linkage with outsourcing; it is often carried out with extreme outsourcing[140]. This trend is higher in the German automotive production market, mainly because of high labour costs[141].

2.4.3 Review of literature about issue

To cope with the global challenges, and to meet the higher customer demand, most of the companies considered mass customization as their target by the start of the 21st century. Due to diverse customer preferences, higher globalization and advancement in technologies, it has created various problems related to supply chain for the managers. Various studies analyse supply chain practices in mass-customized automobile industries. The analysis of literature shows that although internal factors of manufacturing like production techniques etc. have been focused on, the importance of supply chain management (especially on the central level) and its linkage with mass customization has always remained

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[138]Thun, J. H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. International Journal of Production Economics, 131(1), 242-249.; Rice, J. B., & Caniato, F. (2003). Building a secure and resilient supply network. Supply chain management review, v. 7, no. 5 (sept./oct. 2003), p. 22-30: ill.

[139]Remko I. van Hoek, Harm A.M. Weken, (1998) "The Impact of Modular Production on the Dynamics of Supply Chains",The International Journal of Logistics Management, Vol. 9 Issue: 2, pp. 35-50

[140] http://www.emeraldinsight.com/doi/pdfplus/10.1108/13598540410527024 Seen on Feb 2017

[141]Thun, J. H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. International Journal of Production Economics, 131(1), 242-249.; Frigant, V., & Miollan, S. (2014). The geographical restructuring of the European automobile industry in the 2000s.

an under-researched area[142]. In this section, we discuss the contribution of the studies, which are related to supply chain management in the automotive industry. Based on this analysis we will develop a research gap in the next section.

1. Literature suggests that mass customization is successful in a computer industry and a failure in the automotive industry. It is established that supply chain management plays a critical role in the success of mass customization. The automobile industry failed to benefit from mass customization because of weak supply chain while the computer industry did because of efficient supply chain management[143]. Since producer links with the customer (forward linkage) and producer links with the supplier (backward linkage) are the main drivers of successful mass customization, thus these two important linkages; producer-supplier relation and producer-customer are critical under mass customization. Moreover, since under mass customization, inventories are kept low, so producer relation with the supplier is of extreme importance[144].
2. Another study suggests that the major hurdle for the success of mass customization in the automotive industry is the responsiveness in the supply chain. In the case of the computer industry it is not difficult to make a smart computer in 4 minutes, however in the case of heavy products such as cars, managing time is not that easy. Since the customer is normally not willing to wait for their desired car for more than three weeks, they prefer to go to a car dealer and buy the available car. Thus, for the automotive companies time management is the biggest hurdle, as the car assembling took time. It takes three days only in the paint shop while the companies do not like to paint a car individually, and they like to run car paint in batches[145].
3. Study suggests that in the progress from Build to Storage (BTS) to build to order (BTO), German automotive companies completely changed the structure of supply chain planning. With the innovation of the online order system, there was a significant reduction in the order to delivery time, which is driven by order processing and entry time. For example: BMW AG has managed to reduce lead-time to order delivery from 13-17 days to a single day by the online

[142]Liu, G., &Deitz, G. D. (2011). Linking supply chain management with mass customization capability.International Journal of Physical Distribution & Logistics Management, 41(7), 668-683.; Chandra, C. and Kamrani, A.K. (2004), Mass customization: A supply chain approach, Kluwer Academic/Plenum, New York, NY

[143] Pollard, D., Chuo, S., & Lee, B. (2011).Strategies for mass customization. Journal of Business & Economics Research (JBER), 6(7).

[144]Pollard, D., Chuo, S., & Lee, B. (2011).Strategies for mass customization. Journal of Business & Economics Research (JBER), 6(7).

[145]Solihull, N. (2001). Mass customization: a long march. The Economist: Keeping the Customer Satisfied, 67-19.

order system. This shift to online ordering system has taken mainly traditional assignments, which were previously taken up by the dealer.[146]

4. Customization offered at BMW AG was investigated in one of the works, which explored the nine-customization conditions at BMW AG. The study brings out an interesting finding that the BMW AG Individual collection (IC) program failed to deliver the outcomes it once promised. The set of options offered by BMW AG were analysed qualitatively. Although this analysis was from an introductory study, it brings out an important aspect for investigation that when BMW AG as a whole was progressing, its IC program was still vulnerable and not up to the expectations[147].
5. It is important to note that mass customization has not gained much popularity in the automotive industry of the United States. There can be different reasons to this. The success of mass customization in Dell attracted the US automotive industry to pursue strategies adopted by Dell. Most of the strategies were mainly concerned with modularity. The study concludes that a hindrance in successful mass customization in US automotive industry is that the shift of industry from mass production to mass customization is not accompanied by the changes in the supply chain structure. Major changes in the supply change structure are required to shift to mass customization. This brings out not only the importance of supply chain but also changes of structures[148].
6. Since the Chinese manufacturing context differs significantly from the rest of the world, a study tried to investigate the supply chain practices for mass customization in the automotive industry. The study concluded that only a few MC practices are applicable to the Chinese market. Process modularization, product modularization and supplier segmentation can affect Chinese automotive customization capabilities. Postponement practices were not found to be significant for the Chinese market[149].
7. One of the studies suggests that mass customization may confuse the customers, raising the question "is mass customization in the automotive industry really helping customers or it is just confusing them?" The study investigated that tools which are used to carry out mass customization in the automotive industry are actually confusing customers, the current online configuration systems are unable to identify the real needs of the customer; instead they are confusing

[146]Meyr, H. (2004). Supply chain planning in the German automotive industry. OR spectrum, 26(4), 447-470
[147]Kyle, M. & Jason, C. (2008) Customization at BMW. Harvard Buisness Review
[148]Ro, Y. K., Liker, J. K., & Fixson, S. K. (2007). Modularity as a strategy for supply chain coordination: The case of US auto. IEEE Transactions on Engineering Management, 54(1), 172-189.
[149]Liao, K., Deng, X., & Marsillac, E. (2013). Factors that influence Chinese automotive suppliers' mass customization capabilities. International Journal of Production Economics, 146(1), 25-36.

the customers. The paper focuses on using data mining techniques in order to identify the real needs of the customers. Based on the methodology it recommends the set of options that should be used for customizing engines[150]. This paper brings an insight into the possible reason for the failure of mass customization in a number of companies. It also brings out the fact that the impact of mass customization on customer satisfaction needs to be explored. Moreover, another detailed study about automotive analysis concluded that sustainable competitiveness in the modern automotive industry is only possible via development of customer responsive efficient supply chain that helps to perform operations globally.[151]0

8. Another study investigated risk management processes in 67 manufacturing automobile plants in Germany; it concluded that risk management instruments are implemented to a lower degree. The studies show that globalization, increased variety, outsourcing and reduction of suppliers have increased the vulnerability to the risk. The study aggregated the results of the whole automotive industry by separating the companies into two groups on basis of pursuing reactive or preventive supply chain risk management. It concludes that reactive supply chain management can reduce external risks but it may lead to inefficiencies due to redundancies, while the preventive risk management in the supply chain helps in the creation of resilient supply chain management. This study forms the basis of our study, although it brings out some clear insights into the problems of the automotive industry, but the study explores supply chain risks on the plant level[152].

2.4.4 Research gap

The analysis in the chapter shows that the automotive industry has undergone dynamic policy changes, at different times and in different regions. Although mass customization is the modern trend, which has taken over the industry, the success of this phenomenon depends upon the quality of supply chain management. The analysis of literature shows that few studies have analysed this phenomenon deeply[153], and we find studies that show risk assessment in German automotive companies at plant level. However, we do not find any study that analyses the central supply chain policies of a company

[150]Mavridou, E., Kehagias, D. D., Tzovaras, D., & Hassapis, G. (2013). Mining affective needs of automotive industry customers for building a mass-customization recommender system. Journal of intelligent manufacturing, 1-15.

[151]Holweg, M. (2008).The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13-33.

[152]Thun, J. H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. International Journal of Production Economics, 131(1), 242-249.

[153] Holweg, M. (2008).The evolution of competition in the automotive industry. Build to order: the road to the, 5, 13

that can make companies vulnerable to shocks in the long run. As analysed in this chapter, literature has showed that there has been high regionalization in the automotive industry, high dependence on outsourcing, problems with downstream supply chain (with mass customization), inventory management problems, frequent policy changes etc. However, we do not find any studies investigating the issue of high dependence on the supplier, outsourcing and influence of other such techniques on the OEMs supply chain. As shown in table 2-1, there is no such study, which evaluates differences in modern supply chain practices in different automotive companies, their risks and vulnerability under mass customization under the German market. Moreover, we failed to find papers using case studies from different companies (within industry) to evaluate the vulnerability of the modern supply chain especially in the automotive industry. Such analysis of different companies within the same industry would help us to differentiate the supply chain policies that could be more fruitful under this dynamic mass customization environment.

	Issues discussed							
	Mass customization	**Risk analysis**	**Automotive industry**	**supply chain policies**	**European market**	**Outsourcing and modularization**	**Case studies comparison with in industry**	**Downstream supply chain**
Helweg 2008	Yes	No	Yes	To some extent	Yes	Yes	No	No
Liu2 011	Yes	No	Not specifically	Yes	No	No	No	No
Solihull 2001	Yes	No	Yes	No	No	No	No	No
Pollard 2011	Yes	No	Yes	No	No	No	No	No
Meyr 2004	Yes	No	No	No	Yes	No	No	No
Murray 2008	Yes	No	Yes	No	No	No	No	No
Ro 2007	Yes	No	Yes	No	No	No	No	No
Liao 2013	Yes	No	Yes	No	No	No	No	No
Mavridou 2013	Yes	No	No	No	No	No	No	Yes
Morris	No	No	Yes	Yes	No	Yes	No	No
Cabigiosu, 2013	Yes	No	Yes	Yes	No	Yes	No	No
Thun 2011	Yes	Yes	Yes	No	Yes	Yes	No	No
Boysen 2015	Yes	No	Yes	Yes	No	No	No	No
Ambe 2010	No	No	Yes	Yes	No	Yes	No	No

Table 2-1: Analysis of literature

2.5 Research question confirmation from research gap

The literature analysis confirms there is no such study, which evaluates supply chain policies under mass customization on industrial level, in automotive industry. Although there are few studies developed, but these are on plant level. An analysis within the industries, between the companies from the same country, will help to deduce which policies are more efficient. Such comparative analysis can also help to determine what the conditions that lead to more risk situations are. Under the light of the mentioned arguments, it can be seen that the research question "which policies of supply chain are more efficient under mass customization?" is highly relevant.

For addressing the research question this study will carry out three case studies from the German automotive industry. Since all the companies are from the same countries, so it can be assumed that all three companies face same laws and conditions. This would help us to differentiate that under the dynamic environment of mass customization; how the supply chain policies are variable within the industry, which policies are more stable, which practices made the supply chain less risky and how the downstream supply chain is influencing mass customization. In this regard, three major German automotive companies are evaluated. More specifically, how these companies are managing the following aspects:

- Relations with suppliers
- Outsourcing and modularization
- Control over supply chain
- Managing modern supply chain practices
- Risk management
- Control over manufacturing
- Dynamic environment
- Extent of Mass customization
- Dependence in supply chain
- Management of supply chain tools
- Globalization of markets and production
- Issues with downstream supply chain
- Inventories Management

The resulting comparison would help to describe the best practices, which would be highly beneficial to the automotive companies and therefore would be a significant contribution to literature

3 Case study analysis of supply chain strategies

This chapter is focused to investigate practices which lead to efficient supply chain management under mass customization. This question would be addressed using case study analysis of three German automotive companies, supply chain policies of all three companies will be analyzed, it will be further investigated that which of these company has performed better in supply chain performances indexes and has suffered lowest number of incidents. Based on this analysis, the final part will differentiate between the efficient and risky supply chain policies.

For this purpose, firstly a structure for analyzing the supply chain policies will be developed in section 3.1, this framework will describe the structure, strategies and components of supply chain. Next, three automotive companies case studies would be investigated in section 3.2, using the previously developed framework of section 3.1. I section 3.3 comparative critical analysis would be carried out. The structure of this chapter is described in Figure 3-1.

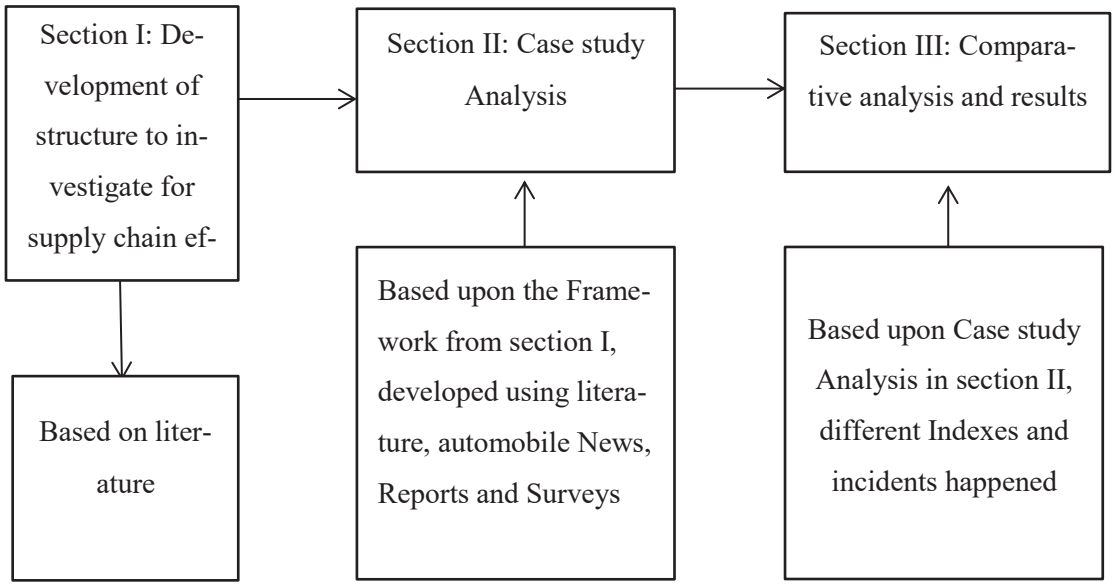

Figure 3-1: Structure of the chapter

3.1 Model Structure for supply chain analysis

In this section, different issues to describe the nature of interrelated supply chain elements are discussed and a model is developed from them, this model will be used to evaluate case studies in the next section. Since in the modern times, supply chain in automotive industry has to be managed for the mass customized automobiles, while it is observed that number of options are increasing with time, which results in millions of car combinations, these increasing options also increases the number of parts that have to be handled. Moreover car manufacturers allow customer to update their configuration even 6 days before manufacturing[154]. These modern trends have increased complexity in the supply chain system as increased number of parts from a wide range of suppliers, in short planning and delivery times are to be managed[155]. This requires an efficient planning within the interrelated supply chain elements and structure. To evaluate this supply chain structure and elements, a structure is developed in this section based on the literature studies[156] , as developed in literature, a typical supply chain system consist of three closely related elements; supply chain management components, supply chain business process and supply chain network structure[157]. These three components can be stated as follows:

- **Supply chain Network structure:** Extensity of members
- **Supply chain business process:** Strategies and linkages of members
- **Supply chain management components:** Managerial tools used to manage supply chain processes across the supply chain

All these three elements cover important supply chain relations, policies and elements. The complete structure of supply chain, describing these three elements and their further relations is shown in Figure 3-2; this framework is developed upon the bases of literature[158].

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[154] Lin, Y., Ma, S., & Zhou, L. (2012). Manufacturing strategies for time based competitive advantages. Industrial Management & Data Systems, 112(5), 729-747.

[155] Boysen, N., Emde, S., Hoeck, M., & Kauderer, M. (2015). Part logistics in the automotive industry: Decision problems, literature review and research agenda. European Journal of Operational Research, 242(1), 107-120.

[156] Lambert, D. M., & Cooper, M. C. (2000). Issues in supply chain management. Industrial marketing management, 29(1), 65-83.

[157]Lambert, D. M., & Cooper, M. C. (2000). Issues in supply chain management. Industrial marketing management, 29(1), 65-83.

[158] Lambert, D. M., & Cooper, M. C. (2000). Issues in supply chain management. Industrial marketing management, 29(1), 65-83.

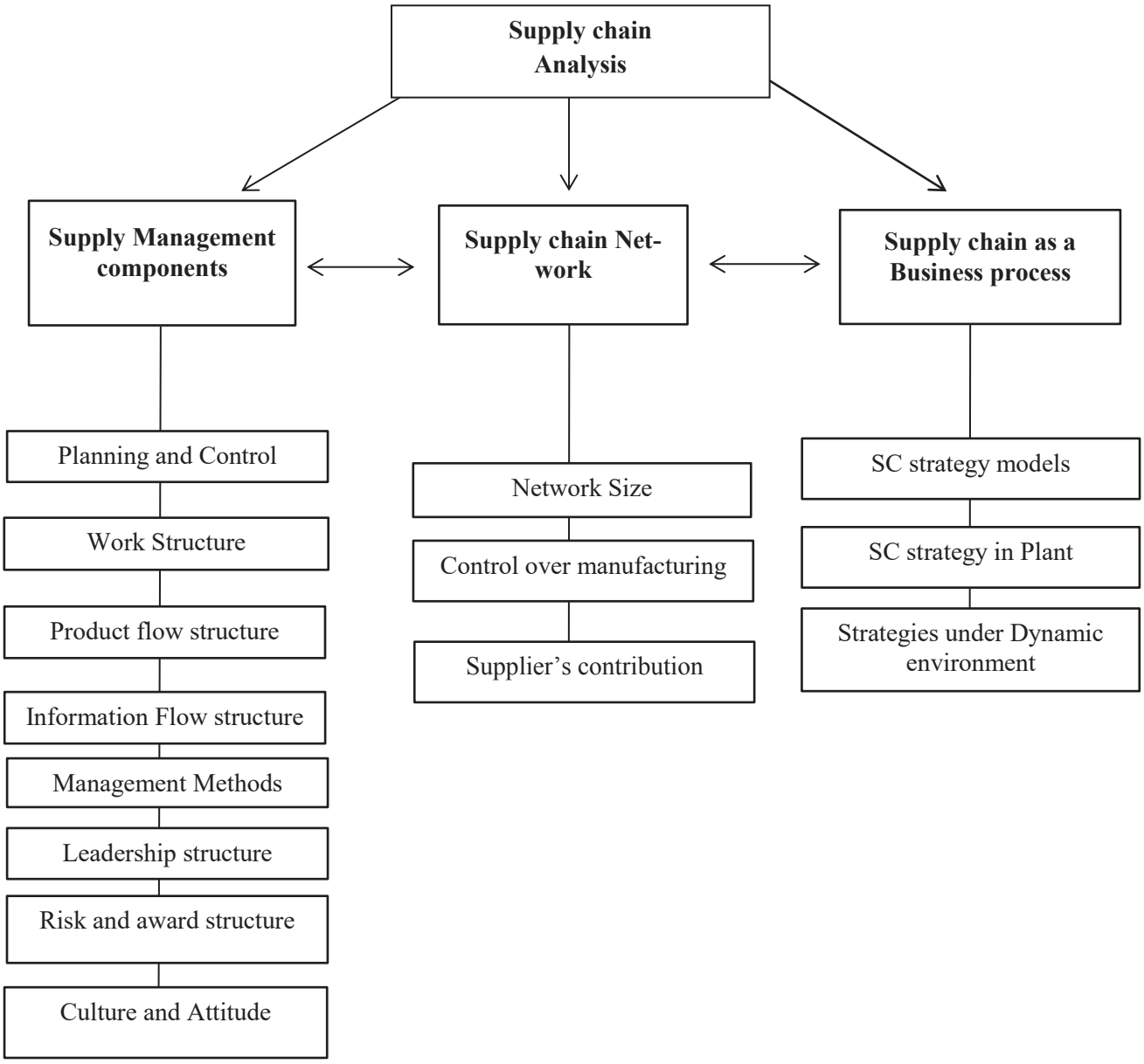

Figure 3-2: Model structure for supply chain analysis

3.1.1 Supply chain network structure

Supply chain is like a pipe line, where suppliers are like branches of tress; the question for every manufacturer is that how many branches should be or in other words what should be the number of suppliers in the supply chain. It has been investigated that increasing or decreasing the number of suppliers affect the structure of supply chain and can result in a completely new structure. If a company moves from single supplier to multiple suppliers than the network of supply chain become much more extensive and vice versa[159]. To understand the modern supply chain network structure, the factors and facts that have affected the supply chain network, will be discussed in this section.

3.1.1.1 **Network size**

Supply chain network size has squeezed with modern techniques. One of the main reasons is the adoption of Modularization. Nowadays suppliers are supposed to deliver a complete module, rather than smaller components[160]. The most prominent benefit for automotive companies from this shift to modularization is that new vehicles are produced with less time and cost by mixing and matching components[161].

This approach means a lot of value is added to suppliers in the supply chain. The previously work done by the OEM is shifted to the supplier. The complexity of the product is shifted to the supplier. In this scenario, the supply chain network is completely changed as the supplier in the network decreases. This may reduce the complexity for the OEMs as there are less direct suppliers to deal with. One of the examples of network change through modularization is of Mercedes-Benz smart car. A typical car involve around 200-250 suppliers, however New smart Mercedes-Benz sports car has higher level of customization thus comprises high number of modules but from as low number of suppliers as 25. So this mode of production has shifted the supplier producer relation. Instead of communicating with the

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[159]Lambert, D. M., & Cooper, M. C. (2000). Issues in supply chain management. Industrial marketing management, 29(1), 65-83.

[160]Doran, D., Hill, A., Hwang, K. S., Jacob, G., & Operations Research Group. (2007). Supply chain modularization: Cases from the French automobile industry. International Journal of Production Economics, 106(1), 2-11.

[161]Doran, D., Hill, A., Hwang, K. S., Jacob, G., & Operations Research Group. (2007). Supply chain modularization: Cases from the French automobile industry. International Journal of Production Economics, 106(1), 2-11.; Sanchez, R., Collins, R., (2001). Competing and learning in modular markets. Long Range Planning 34 (6), 645–667.

large number of suppliers, OEMs have to communicate with the less number of suppliers[162]. Supplier Integration in the modern production can be seen at several levels. The supply prospective can be attributed in the following factors of modern production, JIT, BTO; Modular product strategy[163], these techniques require higher integration between supplier and producer.

3.1.1.2 **Control over manufacturing**

Suppliers control over manufacturing has increased in automotive industry. Outsourcing can be considered as a major reason behind this. Outsourcing in the automotive industry started in late 90s and has taken much of the automotive industry under its influence[164]. Assembly plants in Europe are characterized by the high degree of outsourcing as modularization is always accompanied by outsourcing; this relation changes the supply chain structure. Although outsourcing has its own benefits, it may affect the future capacity of the firm as the structure of supply chain changes[165]. It is always followed by a risk that automaker loose the control of manufacturing, if the supplier producer relation changes it affects the manufacturability of the OEM[166]. Moreover, once outsourcing has been adopted the decision to reverse it has heavy costs[167].

3.1.1.3 **Supplier contribution**

Due to advancement in technologies automotive manufacturers believe now that they may not have all the expertise in all the areas. It has become far more difficult for OEMs to get expertise in all of the fields of modern automotive industry As a result; the automotive companies now prefer to produce

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[162]Doran, D., Hill, A., Hwang, K. S., Jacob, G., & Operations Research Group. (2007). Supply chain modularization: Cases from the French automobile industry. International Journal of Production Economics, 106(1), 2-11

[163]Bennett, D., & Klug, F. (2012).Logistics supplier integration in the automotive industry. International Journal of Operations & Production Management, 32(11), 1281-1305.

[164]Harrison, A. (2004). Outsourcing in the automotive industry: the elusive goal of tier 0.5. Manufacturing Engineer, 83(1), 42-45.

[165]Aláez-Aller, R., & Carlos Longás-García, J. (2010). Dynamic supplier management in the automotive industry. International Journal of Operations & Production Management, 30(3), 312-335.; Cousins, P. D. (1999). Supply base rationalization: myth or reality? European Journal of Purchasing & Supply Management, 5(3), 143-155.

[166]Aláez-Aller, R., & Carlos Longás-García, J. (2010). Dynamic supplier management in the automotive industry. International Journal of Operations & Production Management, 30(3), 312-335; Gadde, L.E. and Jellbo, O. (2002), "System sourcing-opportunities and problems", European Journal of Purchasing & Supply Management, Vol. 8, pp. 43-51.

[167]Aláez-Aller, R., & Carlos Longás-García, J. (2010). Dynamic supplier management in the automotive industry.International Journal of Operations & Production Management, 30(3), 312-335; Dankbaar, B. (2007), "Global sourcing and innovation: the consequences of losing both organizational and geographical proximity", European Planning Studies, Vol. 15, pp. 271-88.

cars in a close collaboration with the suppliers. The modern assembling methods focus to satisfy diversification of demand. This has led to the situation in which producer highly depend upon the supplier. This strong relation between supplier and producer is not only focused to gain economic benefits but also long term research and innovation goals[168]. This reliance is affecting the network structure of supply chain. Nowadays automotive supplier constitutes almost 70 to 80 % of the whole value creation. As a result of this shift, the management of supplier has got considerable importance as much as in house value creation[169].

3.1.2 Supply chain business processes

Modern supply chain demands that different supply chain components integrate with each other, rather than acting as a separate entity. Traditionally, upstream and downstream supply chain has acted as separate entities not collaborating on different levels[170]. However, producer-supplier relation has changed a lot in the last decade, with the introduction of modular production, outsourcing and just in time, high coordination in logistics and manufacturing process has become an essential requirement[171]. To optimize the product flow it is important to implement process approach in the business to coordinate different elements.

For the elaboration of business processes in the supply chain, it is important to elaborate end to end supply chain flow, which is describes in Figure 3-3. The flow of material is from the supplier to the customer but the flow of information is two ways.

[168]Morris, D., Donnelly, T., & Donnelly, T. (2004). Supplier parks in the automotive industry. Supply Chain Management: An International Journal, 9(2), 129-133.

[169]Bennett, D., & Klug, F. (2012).Logistics supplier integration in the automotive industry. International Journal of Operations & Production Management, 32(11), 1281-1305. ; Harrison, A. (2004). Outsourcing in the automotive industry: the elusive goal of tier 0.5. Manufacturing Engineer, 83(1), 42-45.

[170] Lambert, D. M., & Cooper, M. C. (2000). Issues in supply chain management. Industrial marketing management, 29(1), 65-83.

[171] Larsson, A. (2002). The development and regional significance of the automotive industry: supplier parks in Western Europe. International Journal of Urban and Regional Research, 26(4), 767-784.

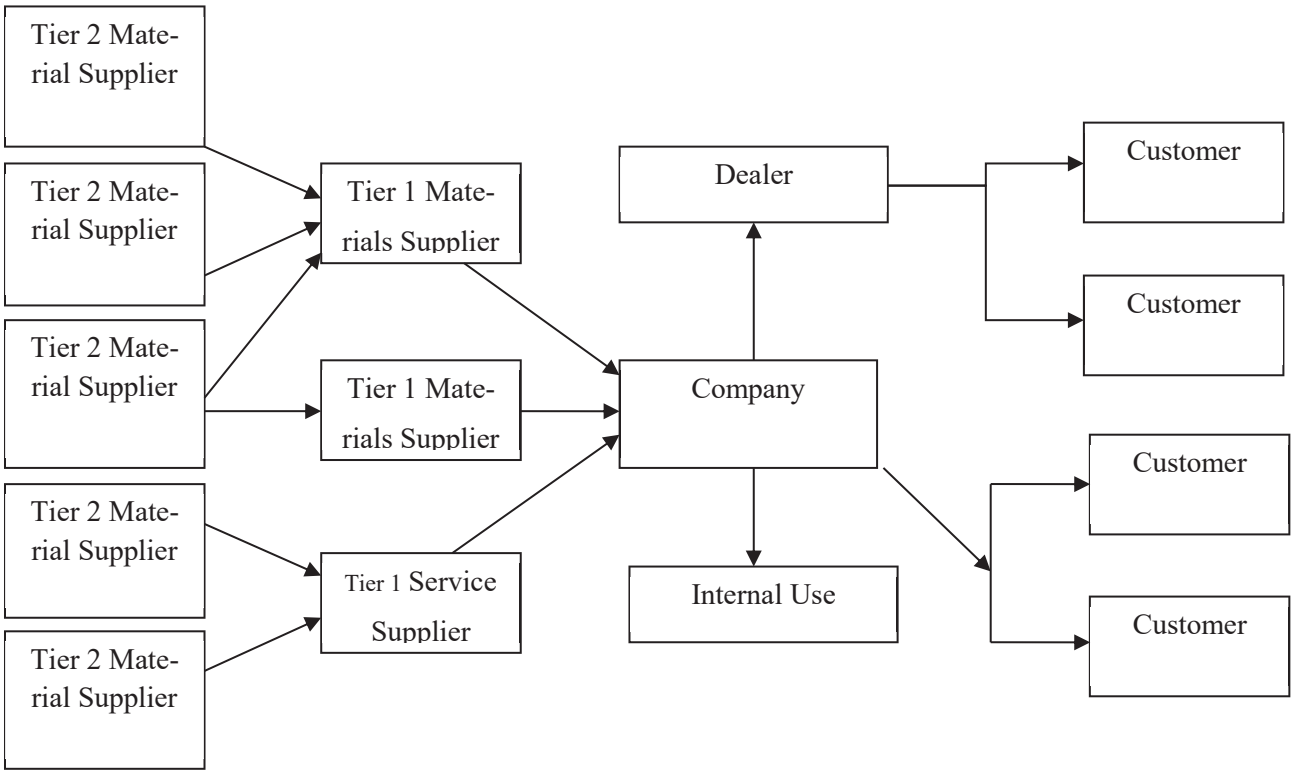

Figure 3-3: End to End Flow in supply chain

Source: Techtransfer (2017) [172]

3.1.2.1 **Supply strategy models**

Supply chain management needs to consider both internal and external factors. External SCM conditions comprise of relationship related characteristics between supply chain partners, these conditions can be considered as an essential aspect for SCM related process[173]. Different supply chain strategies have been developed to maintain such relations with external partners. Moreover, supply chain strategies are implemented in the OEMs to achieve the competitive advantage, these strategies gives insight into the relations priority in the supply chain. In the automotive industry, there are two famous model to interpret supply chain strategies, arm length model (market based) and partnership (based on cooperation), the arm's length model was more famous among Western automakers till 1980 while the Partnership model was famous among Japanese automakers[174]. In

[172] https://www.techtransfer.com/tag/end-to-end-supply-chain-flow/ Seen on July 2017

[173] Kotzab, H., Teller, C., Grant, D. B., & Sparks, L. (2011). Antecedents for the adoption and execution of supply chain management. Supply Chain Management: An International Journal, 16(4), 231-245.

[174] Aláez-Aller, R., & Carlos Longás-García, J. (2010). Dynamic supplier management in the automotive industry. International Journal of Operations & Production Management, 30(3), 312-335.; Kim, J.-B. and Michell, P. (1999), "Relationship marketing in Japan: the buyer-supplier relationships of four automakers", Journal of Business & Industrial Marketing, Vol. 14 No. 2, pp. 118-29 ; Okamuro, H. (2001), "Risk sharing in the supplier

the former mode, the supplier does not involve in overall process and provider what the buyer asks; priority is given to the buyer in this process while in the later model focus is on mutual cooperation, high exchange of information, and mutual trust. Arm-length model was considered as a traditional practice in the automakers[175].

The supplier strategy adopted by the automakers depends largely upon the changes occurring in the industry and on the automaker own experience and history[176]. Although earlier studies suggest that these both models cannot run in parallel and firms have to choose among them[177]. However, later studies suggest differently as it has been found that due to dynamic changes, automotive companies apply different kind of strategies with different type of suppliers. Partnership based relationships are used with the suppliers of components (parts) and systems which involve high level of technology and also with those suppliers who can make automakers vulnerable to large risks[178]. With all other suppliers the OEM does not go for partnership models. Volkswagen AG which has believed in global sourcing always went on to move towards partnership model in 2005 and tried to establish relation with some "hard core" supplies with which company will work on partnership bases. It has been suggested that arm length model and partnership models are displaced by the strategies that encompasses the features of both of these models[179].

Furthermore, recent development has changed the strategies in the supply chain up to large extent. The traditional models have changed to accompany new changes. There are three main reasons that have affected strategies in the supply chain, these reasons are

- Advancement in technology

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relationship: new evidence from the Japanese automotive industry", Journal of Economic Behavior & Organization, Vol. 45, pp. 361-81.

[175] Johnston (2005), Partnering for Lean Manufacturing, SCRC articles

[176] Aláez-Aller, R., & Carlos Longás-García, J. (2010). Dynamic supplier management in the automotive industry. International Journal of Operations & Production Management, 30(3), 312-335; Sturgeon, T., van Biesebroeck, J. and Gereffi, G. (2008), "Value chains, networks and clusters: reframing the global automotive industry", Journal of Economic Geography, Vol. 8, pp. 297-321.

[177] Aláez-Aller, R., & Carlos Longás-García, J. (2010). Dynamic supplier management in the automotive industry. International Journal of Operations & Production Management, 30(3), 312-335; Cusumano, M. A., & Takeishi, A. (1991). Supplier relations and management: a survey of Japanese, Japanese-transplant, and US auto plants. Strategic Management Journal, 12(8), 563-588.

[178] Aláez-Aller, R., & Carlos Longás-García, J. (2010). Dynamic supplier management in the automotive industry. International Journal of Operations & Production Management, 30(3), 312-335; Pe´rez, M. and Sa´nchez, A. (2001), "Supplier relations and flexibility in the Spanish automotive industry", Supply Chain Management: An International Journal, Vol. 6, pp. 29-38.

[179] Aláez-Aller, R., & Carlos Longás-García, J. (2010). Dynamic supplier management in the automotive industry. International Journal of Operations & Production Management, 30(3), 312-335

- Realization by the automotive manufacturers about their dependence upon supplier
- Modularization

3.1.2.2 **Supply chain relations under dynamic environment**

To overcome the challenges of customization problems, high competition and fast growing modern technology automotive industry move towards the lean production system. Lean production system can be defined as "as a model where the persons assume a role of thinkers and their involvement promotes the continuous improvement and gives companies the agility they need to face the market demands and environment changes of today and tomorrow " [180]. Today many strategies of lean production system like Just in time are applied on large scale in automotive industry. This production system has completely changed the network structure within the organization system.

By the start of 21 century, mass customization was the newest attraction for the automobile companies, in this scenario JIT was not the only popular approach. Many automotive companies started to shift from the JIT to the new approaches like modular consortia and integrated supply. Volkswagen AG was more attracted towards modular consortia. The modular approach has given the supplier much higher weightage, the supplier has become one of the key player in the supply chain. Due to this approach many first tier supplier in in the first decade of 21 century either become the modular supplier or become the supplier of the module supplier. It further leads to the situation where the first tier supplier was responsible for the entire supply chain for a particular module. Volkswagen AG thus looked forward to have a stable relationship with few suppliers who could form a stronger base for a long term relationship[181]. Further analysis of characteristics of lean manufacturing system, which has impacted the supply chain relations, is given below:

3.1.2.3 **Reliable suppliers for Just in time delivery**

Just in time has become one of the important feature in modern automotive industry, this process reduce inventories at the OEMs[182]. The main focus of just in time is to reduce inventories; the production of the final good depends on the on time delivers of the components (or modules in the case of modular production). This system demands that producer and supplier work together to reduce the inefficiencies

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[180] Jaiprakash Bhamu, Kuldip Singh Sangwan, (2014) "Lean manufacturing: literature review and research issues", International Journal of Operations & Production Management, Vol. 34 Issue: 7, pp.876-940, ; Alves, A.C., Dinis-Carvalho, J. and Sousa, R.M. (2012), "Lean production as promoter of thinkers to achieve companies' agility", The Learning Organization, Vol. 19 No. 3, pp. 219-237.

[181] Collins, R., Bechler, K., & Pires, S. (1997). Outsourcing in the automotive industry: from JIT to modular consortia. European management journal, 15(5), 498-508.

[182] Boysen, N., Emde, S., Hoeck, M., & Kauderer, M. (2015). Part logistics in the automotive industry: Decision problems, literature review and research agenda. European Journal of Operational Research, 242(1), 107-120.

in the system. The literature shows that a cost saving could be achieved if the sophisticated coordination mechanism is implemented between supplier and producer and coordination is trustful.[183]

Most of the OEM now has the sole suppliers which are hardly related to the local and regional economy. These suppliers establish supplier parks near the manufacturing point and ensures the just in time deliveries. Most of the automobile companies are relying on the reliable deliveries from such suppliers[184]. Moreover the supplier producer distance could have higher implications on the production costs[185]. However there is no empirical testing of the relation, such models are not tested in real world criteria's, so to explore the risks associated with distance there is demand for empirical evaluation. The impact of geographical situations on supply chain management will be discussed in detail in next chapter.

3.1.2.4 **Flexible manufacturing**

Due to unexpected demands, higher expectations of customers and global spreads of supply chain the level of risk in the system increases many folds. Therefore, in global scenario it is very important that the supply chains are flexible[186]. Flexibility in the supply chain is rather a new area in the literature. Supply chain flexibility is related to the application of supply chain resources according to dynamic conditions of the market while requiring the firms to establish cross-company and cross-functional strategies which can remove any bottlenecks and create a level of performance that enables firms to increase their competitive advantage in unpredictable environment[187]. Although supply chain flexibility does not always lead to higher profits, but the level of flexibility needs to be aligned with the supply chain requirements, in order to maintain efficiency in the system[188]. It can help companies in decision

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[183] Zimmer, K. (2002). Supply chain coordination with uncertain just-in-time delivery. International journal of production economics, 77(1), 1-15.

[184] Larsson, A. (2002). The development and regional significance of the automotive industry: supplier parks in Western Europe. International Journal of Urban and Regional Research, 26(4), 767-784.

[185] Ghodsypour, S. H., &O'brien, C. (2001). The total cost of logistics in supplier selection, under conditions of multiple sourcing, multiple criteria and capacity constraint. International journal of production economics, 73(1), 15-27.

[186] Blome, C., Schoenherr, T., & Eckstein, D. (2014). The impact of knowledge transfer and complexity on supply chain flexibility: A knowledge-based view. International Journal of Production Economics, 147, 307-316.

[187]Thomé, A. M. T., Scavarda, L. F., Pires, S. R., Ceryno, P., & Klingebiel, K. (2014). A multi-tier study on supply chain flexibility in the automotive industry. International Journal of Production Economics, 158, 91-105.; Moon, K. K. L., Yi, C. Y., & Ngai, E. W. T. (2012). An instrument for measuring supply chain flexibility for the textile and clothing companies. European Journal of Operational Research, 222(2), 191-203.

[188] Thomé, A. M. T., Scavarda, L. F., Pires, S. R., Ceryno, P., & Klingebiel, K. (2014). A multi-tier study on supply chain flexibility in the automotive industry. International Journal of Production Economics, 158, 91-105.

making processes and help companies to adapt frequently to the market requirements[189]. Any supply chain strategy, model or business plan thus should ensure that there is maximum flexibility in the supply chain. When a supply chain competes with other supply chain, the supply chains which are more flexible outperform those ones which are less agile. This shows that in modern world supply chain flexibility has emerged as a new market strategy to achieve efficiency[190].

3.1.2.5 **Close relationship with supplier**

As discussed previously, the relation between supplier and producer has changed a lot. More reliance on one supplier is increasing[191]. Another important aspect that has emerged is the preference of suppliers which have international manufacturing operation, instead of going for the local suppliers, OEMs relies on the (trusty, sole) same supplier in the different locations. The opportunities for local suppliers thus decrease[192]. It is very important for each company in the supply chain to consider supply chain from the prospective of other member as well. Since each member of the supply chain will consider its company as a focal company and will consider supply chain from its own prospective. The management of each company in supply chain should consider their interrelated roles and prospective[193].
Since the relationship between producer and supplier is based on high dependence, there is a need for trust. A trustful collaborative relationship and reliability can decrease the purchasing costs and can increase the financial performance of the buyer (automotive company)[194]

3.1.2.6 **Supply chain at plant level**

There is continuous flow of material upstream in an assembly plant of automotive manufacturer while there is a downstream divergent flow of finished cars. It is difficult to coordinate all these activities at the plant because production capacity, incoming goods and work force can turn out to be in bottlenecks,

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[189] Jangga, R., Ali, N. M., Ismail, M., & Sahari, N. (2015). Effect of environmental uncertainty and supply chain flexibility towards supply chain innovation: An exploratory study. Procedia Economics and Finance, 31, 262-268.
[190] Jangga, R., Ali, N. M., Ismail, M., & Sahari, N. (2015). Effect of environmental uncertainty and supply chain flexibility towards supply chain innovation: An exploratory study. Procedia Economics and Finance, 31, 262-268.
[191] Larsson, A. (2002). The development and regional significance of the automotive industry: supplier parks in Western Europe. International Journal of Urban and Regional Research, 26(4), 767-784.
[192] Humphrey, J., & Memedovic, O. (2003). The global automotive industry value chain: What prospects for upgrading by developing countries?
[193] Lambert, D. M., & Cooper, M. C. (2000). Issues in supply chain management. Industrial marketing management, 29(1), 65-83.
[194] Corsten, D., & Felde, J. (2005). Exploring the performance effects of key-supplier collaboration: an empirical investigation into Swiss buyer-supplier relationships. International Journal of Physical Distribution & Logistics Management, 35(6), 445-461.

due to these reasons delays in delivery can occur. Thus all the activities in plants need to by synchronize with the planning, as the planning of tasks are carried out at several levels. More commonly, automotive manufacture prepare midterm plans for the suppliers to address the issues of the bottlenecks while in short term daily plans are sent to the suppliers. The management and issues at plant level can seriously affect the supply chain flow[195]. The flow of information, although in the supply chain is normally from producer to the supplier, however when the supplier has equal or more knowledge about the product this information flow can be two ways.

3.1.3 Supply chain management components

The supply chain management components discusses that what level of integration and management should be applied to each member of supply chain. It was investigated that seven types wastages in the production, such as over production, redundant transportation, queue time, excessive storage, unnecessary operations, assembling of defective parts and inappropriate processed results because of failure in supply chain management components (such as less information flow, inefficient work structure and failure of management methods). [196]

These components are already identified in the literature; the nine components identified are discussed below[197]:

Planning and control

The success of supply chain depends upon the planning and control over supply chain components, different components have different importance at different stages, the control aspects can be operationalized as the best performance metrics.

The work structure

The work structure indicates how to organize the task and activities within the firm. Organization structure is accessed through the level of integration.

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[195] Meyr, H. (2004). Supply chain planning in the German automotive industry. OR spectrum, 26(4), 447-470.

[196]Csizmazia, R. A. (2014). Reconfiguration of Supply Chain at Volkswagen Group to Develop Global. International Journal of Academic Research in Business and Social Sciences, 4(12), 294.,;Wildemann, H. (2017). Entwicklungslinien der Produktionssysteme in der Automobilindustrie. In Automobillogistik (pp. 161-184). Springer Fachmedien Wiesbaden.

[197] Lambert, D. M., & Cooper, M. C. (2000). Issues in supply chain management. Industrial marketing management, 29(1), 65-83.

Product flow structure

For the international cooperation, interaction between logistics, production and services is very important. The supply chain design needs to incorporate this. In this regard, communication, skills, logistics product planning and system integration is of vital importance[198]. This structure describes the main network structure of the supply chain for sourcing, manufacturing and distribution across the supply chain. Inventory management is an important aspect in the product flow structure. It is always less expensive to keep raw inventories as compared to the finish ones, so normally if upstream member bears more burden than it's less expensive. Rationalizing the supply chain network has implication for all of the members.

Organizational structure

The term is used to describe the individual firm or the individual supply chain structure, the cross functional teams are used to make the supply chain more integrated.

Information flow structure

Literature agrees that the information flow facility structure is the key of successful supply chain, the kind of information transferred the flow of information and the frequency with which it is updated has a strong influence on the supply chain strength. This is the main source of integration among the different components.

Management methods

This term covers the management techniques followed under corporate philosophy. The level of management influence on supply chain daily activities is different in different supply chain.

Leadership structure

This chain is normally driven by one strong leader, studies shows that mostly there are either one or two such leaders in each cooperation. If there is absence or extreme lack of management influence over supply chain activities it can affect the level of commitment at different channels levels.

Risks and reward structure

The long term commitment of the members in the supply chain is impacted by the rewards they receive and risk they face, the long term supplier-producer relation depends upon this factor as well.

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[198] Haasis, H. D. (2008). Knowledge management in intermodal logistics networks. In Dynamics in Logistics (pp. 269-275). Springer, Berlin, Heidelberg.

Culture and attitude

Nowadays the international environment in the organizations has created very interesting situation, it is interesting, different aspects of culture include how the employees are valued and how they are incorporated in the management of the firm.

3.2 Case study analysis of Mercedes-Benz

3.2.1 Overview of company and its system

A Mercedes-Benz is considered as 13 largest automotive manufacturers in the world, it has extensive supply chain, with network of suppliers from all over the world[199]. It is sub division of a German company Daimler AG. The brand is mainly famous for the Daimler AG. Car division of Mercedes-Benz has six sub brands, while about seven main models are produced under these three sub-divisions, by the company[200]. Figure 3-4 shows the major sub division of the Mercedes-Benz brand.

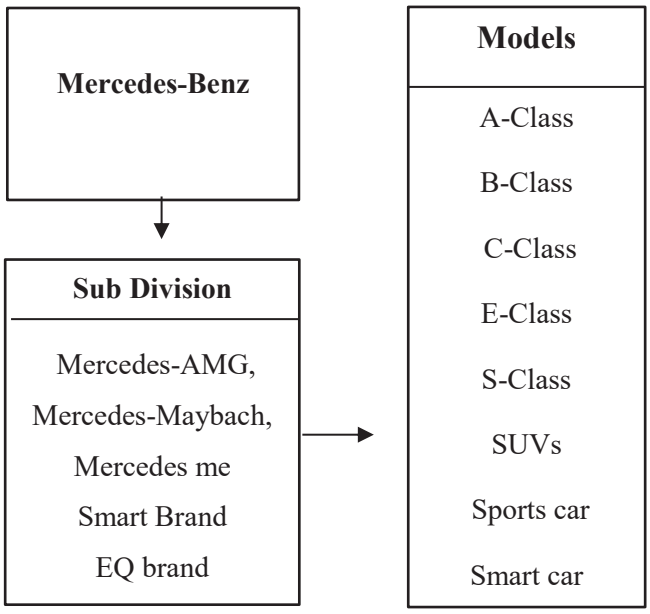

Figure 3-4: Mercedes-Benz-Brand division

[199]http://www.investopedia.com/ask/answers/060815/who-are-daimler-mercedes-dai-main-suppliers.asp Seen on May 2016

[200] https://www.daimler.com/documents/company/business-units/daimler-mbc-ataglance-2017.pdf Seen on May 2016

Merger, crises and current stand

Mercedes-Benz goes through ups and down in its journey, these ups and downs also impact companies' management strategies and customization preferences[201]. In 1998, there was a nightmare for the supply chain strategy, a merger between Daimler AG and Chrysler, gives a lesson for the supply chain strategy. The two companies had a completely different business model; Chrysler was a company focused on modular products with aim to reduce cost, while the Mercedes-Benz focused was on quality and luxury no matter whatever is the price. Most of the parts at Chrysler were outsourced and standardized, while in Mercedes-Benz the engineers were used to design high quality specific parts related to each model, widely known for durability and quality. Chrysler had minimum internal technical engineering thus relying more on the supplier while Mercedes-Benz controlled the work at its supply base. After parent company of Mercedes-Benz, Daimler AG joined America Chrysler in 1998; the resulted new company Daimler AG Chrysler AG started facing high losses. At the time of merger, Chrysler was facing losses however till 2005 the brand Chrysler regained its name however Mercedes-Benz lost its position as its customer started to move towards, Audi, BMW AG etc. This failure is attributed to operational strategies[202]. In short, Chrysler business model was not designed to maintain quality, luxury and durability associated with the Mercedes-Benz do not brand while nor the Mercedes-Benz model was designed to focus on speed delivery and low cost. The result of this merger was that two companies suffered several years because of this merger. For Mercedes-Benz the problems were worse, when publicized by J.D power published survey pin point the problem in Mercedes-Benz ben quality[203].

Policies of Mass customization

To cope with the crises and to bring back the brand name, while managing the vast production network Mercedes-Benz preferred to reduce customization. Thus in 2007, Mercedes-Benz reduced the number of variants for many models, especially outside Europe. This action was to make supply chain simpler, flexible and efficient. According to representative from design and development department reducing the variants was strategic plan of Daimler AG Chrysler project[204]. Mercedes-Benz soon realized that

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201 http://www.logisticsandsupplychain.com/mercedes-benz-sets-out-multi-million-euro-logistics-investment/ Seen on May 2016

202 http://www.logisticsandsupplychain.com/mercedes-benz-sets-out-multi-million-euro-logistics-investment/ Seen on May 2016

203 https://www.strategy-business.com/article/05205?gko=8a29a Seen on May 2016

204 http://www.autonews.com/article/20070514/ANA/70510028/mercedes-goal:-more-flexible-and-efficient-supply-chain Seen on May 2016

in this new modern age, with customers getting pickier, limiting the customization is not the option; instead it's better to deal with the issues in the customization. Company launched cars in 2011 with lot of options in the individualization program. An extensive customization program was launched for Mercedes-Benz SLK specifically.

Worldwide Production

Mercedes-Benz has focused on reduced vertical Integration. Company operates worldwide, however the assembling plants are mainly in Europe. Production pattern of Mercedes-Benz cars is shown in Figure 3-5. The Production plants are mainly in Europe. The distribution pattern will be evaluated in detail in Chapter 4.

Figure 3-5: Worldwide production pattern of Mercedes-Benz cars

Source: Slideshare (2017) [205]

After giving this brief history, further we elaborate the issues in the policies at Mercedes-Benz, using the framework already developed in section 3.1.

[205] https://www.slideshare.net/daimlercareer/daimler-locations Seen on May 2016

3.2.2 Supply chain business process

3.2.2.1 **Business model strategy**

Mercedes-Benz was a success with a highly integrated supply chain; however it turned in losses with the merger and shifted focus towards modular approach. Company is still converting to modular approach however needs time to get the past momentum[206]. With the introduction of modular approach, company focused to get in long term partnership contracts with reliable suppliers. These reliable partners ensure JIT secure deliveries[207].

Mercedes-Benz have a network of over 100 suppliers, in many countries Mercedes-Benz has developed the partnership with the suppliers for innovating new technologies, one example of such joint venture is Mercedes-Benz collaboration with the Qualcomm technologies which is aimed to develop a high tech features, the key suppliers of the Mercedes-Benz are ZF Lenksysteme GmbH, Thyssenkrupp AG, Inteva Products, Eagle Ottawa GmbH, Carcoustics International GmbH, Johnson Electric International GmbH and Nemak Europe GmbH[208].

3.2.2.2 **Strategies under dynamic environment**

In the current time, Mercedes-Benz has a large set of variants; these variants increase sensitivity, flexibility and complexity in the working environment. The company is trying to ensure that the incoming production material flow and the transport of newly manufactured vehicle takes less time and is transported in more flexible way. The company's new policy is focusing on lean production, it is targeted to reduce inventories, securing the supply of material in global production networks and ensuring on time deliveries[209].

Mercedes-Benz has a special, The Supply Chain Management organization department, which has more than 7500 employs, apart from these employees there are numerous service provider linked with

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[206] https://www.strategy-business.com/article/05205?gko=8a29a Seen on May 2016

[207] http://www.ai-online.com/Adv/Previous/show_issue.php?id=1880#sthash.cVIE6OfK.dpbs Seen on May 2016

[208]http://www.investopedia.com/ask/answers/060815/who-are-daimler-mercedes-dai-main-suppliers.asp Seen on May 2016

[209]http://s354933259.onlinehome.us/mhi-blog/mercedes-benz-reorganizes-global-supply-chain-network-to-reduce-vehicle-costs-increase-efficiency/ Seen on May 2016

the company. Mercedes-Benz is reconfiguring its supply chain network globally, with the goal of reducing about 20% cost per vehicle. For this reconfiguration, the company is moving close as possible to the market and to the customer[210].

3.2.2.3 **Supply strategy in plants**

Modular approach has reduced the work in plant work. Large production modules, containing heating and air conditioning system, steering column, instrument cluster, cockpit etc. are transported as a single unit from the suppliers to the plants. Smart car, is one of the model that uses very high degree of modularization. Mercedes-Benz has to deal with just 25 module suppliers for this model; the typical benefits are lesser investment and lesser risk for the company. The module suppliers are long term supplying partners[211].

Mercedes-Benz decided that robots no longer are able to deal with so complex task. So the robots number at working place started declining. According to Markus Schaefer, the head of manufacturing at Mercedes-Benz robots can't deal with high level of individualization, so Mercedes-Benz is employing more human. Robots manufacturers started manufacturing Robots that could work with human being and are more flexible in operations. The term "Collaborative robots" is used for such robots which can work along with human. These practices of using collaborative robots are used in BMW AG and Volkswagen AG[212].

3.2.3 Supply chain network

3.2.3.1 **Network size**

Mercedes-Benz does not rely on very large number of suppliers, company believes in policy of few but reliable suppliers. It has network with over hundred suppliers, which include Eagle Ottawa GmbH, Inteva products, ZF Lenksysteme GmbH, ThyssenKrupp AG etc.[213]. Like other automotive companies,

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[210] http://s354933259.onlinehome.us/mhi-blog/mercedes-benz-reorganizes-global-supply-chain-network-to-reduce-vehicle-costs-increase-efficiency/ Seen on May 2016

[211] Doran, D. (2004). Rethinking the supply chain: an automotive perspective. Supply Chain Management: An International Journal, 9(1), 102-109.

[212] http://www.scdigest.com/ontarget/16-03-14-2.php?cid=10418 Seen on May 2016

[213] http://www.investopedia.com/ask/answers/060815/who-are-daimler-mercedes-dai-main-suppliers.asp Seen on May 2016

Mercedes-Benz also focused to target the emerging markets Brazil, Russia, India, and China (BRIC)[214]. Mercedes-Benz focused less supplier approach in more modular designs, A typical Mercedes-Benz car consist of about 100 supplier while some models have as low as 25 suppliers. The benefits that company believes was that company has to deal with less suppliers, who have more responsibility and less risk was belied in[215].

3.2.3.2 **Control over manufacturing**

Mercedes-Benz spend almost half of its research and development budget on the green technologies, this has forced company to outsource some of its major functions. With the high burden of green technologies on Mercedes-Benz budget, company was considering that what is highly needed to be done in-house and what could be outsourced. According to company it would never outsource new architecture development and the safety features, however to focus on research and development, many departments even engineering could be outsourced**[216]**.

Outsourcing in Mercedes-Benz got quite popular after 2010. The company outsources some of its key functions specially related to logistics and supply chain. Mercedes-Benz plant in Kecskemet (Hungary) outsources parts receiving and line feed to Kuhne + Nagel AG in 2013[217]. In August 2015, the logistics activities at Mannheim plant of Mercedes-Benz were outsourced, although this causes an outrage in the employees of the company[218]. In Sindelfingen plant, logistics is also outsourced but with the mutual understanding from the labor, the cost saving techniques was much impressive after outsourcing of the logistic activities at plant[219]. Mercedes-Benz forces its suppliers to implement the Mercedes-Benz regulations in their own plants, according to them the responsibility of the supplier does not end at the door step of the Mercedes-Benz. If the supplier is not complying with the sustainability standards they can face consequences[220]. Even with high degree of outsourcing and heavy partnerships with supplier,

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[214]http://www.investopedia.com/ask/answers/060815/who-are-daimler-mercedes-dai-main-suppliers.asp Seen on May 2016

[215] Doran, D. (2004). Rethinking the supply chain: an automotive perspective. Supply Chain Management: An International Journal, 9(1), 102-109

[216] http://www.motoring.com.au/mercedes-benz-to-outsource-engineering-52799/ Seen on May 2016

[217] http://automotivelogistics.media/intelligence/a-thin-dividing-line-logistics-and-outsourced-labour

[218]https://www.rnz.de/wirtschaft/wirtschaft-regional_artikel,-Wirtschaft-Regional-Daimler-Benz-Mannheim-Outsourcing-sorgt-fuer-Aerger-_arid,114285.html Seen on May 2016

[219] http://automotivelogistics.media/news/labour-flexibility-and-logistics-outsourcing-key-to-daimler-union-deal Seen on May 2016

[220] https://www.daimler.com/sustainability/production/suppliers/ Seen on May 2016

Mercedes-Benz makes sure that it has a complete control of its supplier, inventories and safety stock levels at suppliers are decided by Mercedes-Benz, to avoid risks[221].

3.2.3.3 **Suppliers contribution**

As discussed previously that Mercedes-Benz form long term partnership with reliable suppliers, who are supposed to deliver a complete module. Further aspect of supplier's participation in production can be seen from the fact that at some plants, suppliers were asked to contribute directly by investing at the factory site. Such suppliers than have their specific own areas at the plants. Along with investment and high responsibilities, such suppliers also contribute in the research and development. Such partnerships have been successful so far for the Mercedes-Benz[222].

To abstain from risks, Mercedes-Benz when enter in a specific contract with the supplier it make some important regulations and laws. The supplier has to supply the spare parts for at least 15 years even after the discontinuation of the series production, without any interruption. The delivery should only be made when requested by Daimler AG. Some specific production related to a specific part or some specific part production can only be scrapped with the written consent from the Mercedes-Benz.[223] Such tough regulations have made suppliers to be bounded for the regular supply a streamlined function.

3.2.4 Supply chain management components

Planning control

Mercedes-Benz implemented several strategies to manage supply chain, hours per vehicle are reduced by 40%, this is mainly due to reduced complexity at the production site, and company has managed to increase productivity, as the data shows that from past few years the productivity is on rise, the volume is increasing while the work force remains same. The company redefines each plant strategy periodi-

[221] Needle, D. (2010). Business in context: An introduction to business and its environment. Cengage Learning EMEA.

[222] Lee, H. L. (2002). Aligning supply chain strategies with product uncertainties. California management review, 44(3), 105-119.

[223]https://d3gx8i893xzz0e.cloudfront.net/fileadmin/corporate/company/purchasing/wsd/customer_requirements/mercedes-benz_special_terms.pdf?1480938439 Seen on May 2016

cally; company has focus towards reducing vertical integration. The company ensured to make synchronization at modular product strategy and modular production place equipment strategy[224]. Supply chain activities at Mercedes-Benz are controlled by global supply chain management unit, which has more than 7500 employers. The unit has several responsibilities such as[225]:

- Management of global supply chain management program
- On time deliveries management, on time deliveries of parts ,components from suppliers , facilities to the targeted plants (inbound logistics)
- Ensuring the supply of material to the assembling plants (Intralogistics)
- Managing global transport of a vehicle from production plant to customer around the world (outbound logistics)

Organizational structure and sustainability of supply chain

In 2008, Daimler AG defined sustainability standards for working conditions, human rights, environmental protection, safety, business ethics, and compliance for suppliers. The supplier sustainability standards are the part of a contract between supplier and Mercedes-Benz. Direct supplies should sharply maintain those standards and pass it to upstream value added chains. According to Mercedes-Benz their goal is to promote common cooperation sustainability among large and small firms alike[226]. To make organizational structure more efficient, Mercedes-Benz open a consolidation center in Speyer, where components from the Europe will be consolidated and repacked to be shipped to Asia, china, US and Africa. Mercedes-Benz has production plants outside Europe, but many parts have to be sourced from Europe. This shift has stretched the supply chain; this puts the strain on the system. According to Mercedes-Benz representative, sometimes supply chain and logistics costs increase the production cost. With the construction of new plant in Speyer, the company insured to reduce the logistics costs. Till 2015, the logistics provider in Bremen were solely responsible of shipments of materials from Europe and Germany to the Mercedes-Benz plants abroad, but with this new plant deliveries from the south of the main river does not have to travel a long distance.

Product flow facility

According to Mercedes-Benz 2020 strategy, the company is focusing to get near the customer and markets. Company is focusing to increase the production especially at the plants outside the Germany.

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[224]https://www.daimler.com/dokumente/investoren/kapitalmarkttage/daimler-ir-mercedes-benzcarscapitalmarketdaymarkusschaefer-20150611.pdf Seen on May 2016

[225] http://www.logisticsandsupplychain.com/mercedes-benz-sets-out-multi-million-euro-logistics-investment Seen on May 2016

[226] http://supplier-magazine.daimler.com/en/verschiedene-industrien-einheitliche-standards/ Seen on May 2016

Customization options and large number of engine variety is causing a strain on logistics operations due to increase complexity. The consolidation center in Speyer aims to reduce this complexity, company aims to produce such centers in China and Africa also[227]. Mercedes-Benz realigns the global logistics organization, and invests multi million euros in the project. The basic aim of such investments is to realign the logistics facilities and manage the logistics costs much well. Furthermore the centralized approach in followed by supply chain management department[228].

Management Methods

To promote flexibility in the supply chain, Mercedes-Benz has made close alliance with the suppliers; the location of the supplier is strategy by Mercedes-Benz, when relocation is necessary it is carried out by the joint venture. Often Mercedes-Benz collaborates on labor issues with the suppliers too, e.g. sometime jobs at Eberspacher GmbH (pipes manufacturer) are carried out by the employs of Benz, on the basis on temporary transfer. This concept of integrating with the pipe suppliers comes after the joint planning of different department at Mercedes-Benz. Planning team at Mercedes-Benz has developed a modular exhaust system with the interchangeable parts, this result in 16 different varieties of the pipes. This system rely on number of concepts, in which JIT is leading more over it had to have been built based on flexibility. This development by Mercedes-Benz showed companies focus on variety[229].

With the number of variants growing all the times, the space at the assembling line is getting shorter for the high variants. The workers are asking for more space that needs a lot of cost. Consumer wanting to be different means that Mercedes-Benz targets to add 30 more models by end of the decade[230].

In 2013, apart from traditional website building process, Mercedes-Benz brings social media to attract more customers in building and ordering car, customers could use Instagram for instance to configure and build car. Automaker launched a campaign on social media, known as “take the wheel”. According to the department management of digital marketing of Mercedes-Benz USA, the campaign on Instagram should have to be very organic and sophisticated, even though Instagram has ads on it; it is need to make sure that the customer does not land on another page. This campaign generated almost 87 million impressions in one year; the interest was increased by 540 percent for the brand. Company is

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[227] http://www.logisticsandsupplychain.com/mercedes-benz-sets-out-multi-million-euro-logistics-investment/ Seen on Sept 2017

[228] http://automotivelogistics.media/news/mercedes-benz-to-invest-several-hundred-million-in-global-logistics-realignment Seen on Sept 2017

[229] Needle, D. (2010). Business in context: An introduction to business and its environment. Cengage Learning EMEA.

[230] http://www.bloomberg.com/news/articles/2016-02-25/why-mercedes-is-halting-robots-reign-on-the-production-line Seen on April 2017

keenly following conversations, additional followers, comments etc. to analyze the overall engagement metrics[231].

Risks

Mercedes-Benz takes the direct responsibility to detect risk at early stage, instead of being detected by Daimler AG. For any decision, the risks are assessed thoroughly. For any project, the long term risks are integrated into the decision making process. The risk management system has the responsibility to identify, control, observe and report risks. Management and control systems are integrated into risk management system. The risks are assessed on the probability of reoccurrence and their possible impact. Depending upon their impact on profit; risks are divided into three types Low, medium and high. The employees at risk management system have the responsibility of not only identifying and accessing risk but also to establish measures which can help to avoid such risks. The development of all the risks from individual entities is then addressed. The risks assessed by the Mercedes-Benz division are presented to the management Board and Audit committee of Mercedes-Benz.[232]

One of the useful strategies adopted by Mercedes-Benz is the safety stock levels. Mercedes-Benz decided the level of stocks at some of its supplier, for example at Eberspacker GmbH Mercedes-Benz sets the level of safety stock, and as soon as the level of inventory falls below this agreed level the supplier fills the gap. The manufacturing of the pipes is initiates as soon as the computer detects the level are falling and it triggers the production. The safety stock level can be changed by Mercedes-Benz according to its needs. To cope with the JIT and flexibility, Eberspacker GmbH has kept extra staff and assembling space to meet with variants demand.

During production, a spare of normally all important parts are present near the assembly line so in the case of damage during assembling the spare can reach the line in ten minutes. Each delivering truck is equipped with phones to cope with risk. These all arrangements are due to operational planning, Mercedes-Benz has given considerable importance to planning[233].

Dealership training& dealership facility

Customer has to deal with dealership for parts and pricings[234]. Mercedes-Benz, specifically in USA wants to make the dealer ship programs simpler. Many dealers have been asking Mercedes-Benz to

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[231] http://digiday.com/brands/mercedes-benz-lets-users-build-custom-car-instagram/ Seen on April 2017

[232]http://annualreport2016.daimler.com/management-report/risk-and-opportunity-report/risk-and-opportunity-management-system Seen on April 2017

[233] Needle, D. (2010). Business in context: An introduction to business and its environment. Cengage Learning EMEA.

[234] https://www.linkedin.com/pulse/fatal-flaw-mercedes-benz-sprinters-tom-robertson Seen on April 2017

make some changes in the training requirements. Dealers are asked by the company to implement the autohaus2 program. The deadlines for this program are being postponed due to dealer's pressure. Till May 2016, only 30 out of 375 dealers implanted the program. The dealers have been forcing company to make changes in the leader ship academy training program also, which forces them to leave the store for several days. The dealers have been saying to the company that the Autohaus program should be considered properly is it really important to be implemented, is such cost of implementation worth or not[235].

3.2.5 Summary

The literature shows that the 13th largest automobile company has faced complications due to unmatched merger. A company which focused on Luxury (Mercedes-Benz) combined with company which focused on less cost (Chrysler). The two companies had completely different supply chain approaches, Mercedes-Benz focused on in-house operations while Daimler AG Chrysler focused on modularization. After facing several years of disruptions the ride for the new company smoothened. The noticed characteristics in the supply chain of Mercedes-Benz can be summarized as following key points

1. After 2010, companies focus towards outsourcing increase dramatically, many logistics related activities at different plants were outsourced. The company even target to outsource engineering, thus reducing in-house action as much as possible. This may be cost beneficial to the company but the quality with which the name Mercedes-Benz has been once associated became question mark.
2. Supply chain management has targeted to reduce the hours per vehicle by 40%
3. Less suppliers, but with very strong relation
4. Strong control over suppliers, tough long term contracts
5. Suppliers are bounded to maintain the stocks Mercedes-Benz decide
6. Deciding the location of the suppliers, in order to achieve JIT fully
7. The delivery system need to be very dynamic and flexible, since 2008
8. Consolidation centers are being built in recent times, the purpose of such centers is to arrange and consolidate shipments to other countries, since now the production has been all over the

[235]http://www.autonews.com/article/20160516/RETAIL07/305169924/mercedes-signals-flexibility-on-dealer-training Seen on April 2017

world it is important to ensure, the right part, at right time, at right place, consolidation center is built in Germany for this purpose

9. The company is targeting to add more variants, this needs more space on plant
10. Mercedes-Benz has moved to more human approach in management, thus robot's number is targeted to decline on the work space, instead of big reports small robots are in focus, which can work along with human.
11. Company is improving its dealership facility, it has target of autohaus2 program. Which requires dealership facility to be very modern; however implementation of program has been postponed several times due to pressure by dealers?
12. To interact with customers more friendly, Mercedes-Benz has started interaction with customers via social media, customization is even possible through the online programs on Instagram
13. Reduce vertical Integration, focus on not manufacturing parts by own instead getting it from other party

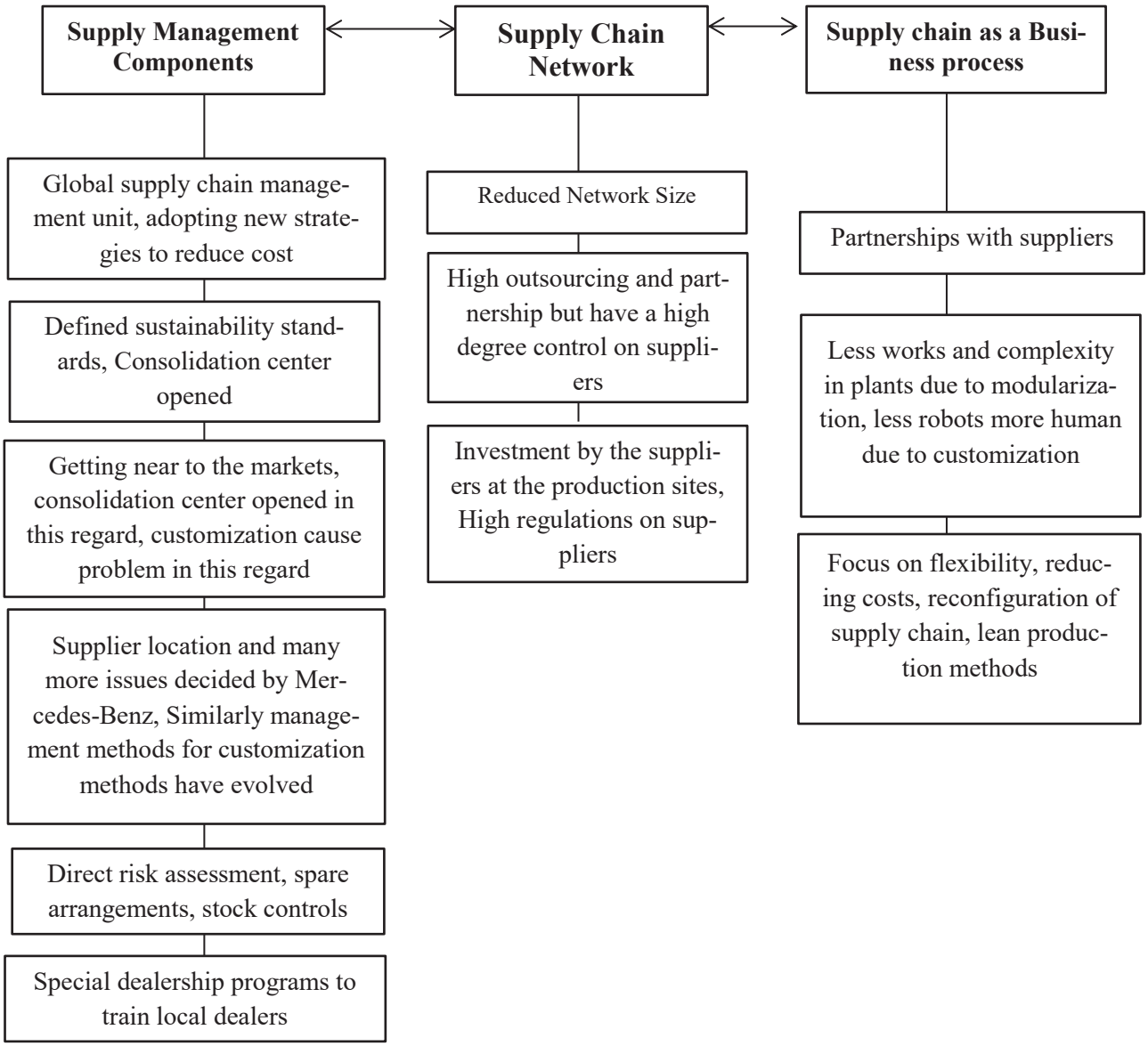

Figure 3-6: Results for Mercedes-Benz supply chain analysis

3.3 Case study analysis of BMW AG

3.3.1 Overview of company and its system

BMW AG, Bavarian Motor Works, is also a German multinational company, it is mainly known for the automobiles. However, it also produces Motorcycles. It was founded in 1916, and has headquarters in Munich. BMW AG is the world's most sustainable company for more than eight years. It manufacture more than 2 million cars annually, it has a network of more than 100 auto parts supplier from different parts of the world, however 50 % of its suppliers are from Germany while 35% of remaining headquarters in the European countries[236]. In 2012 BMW AG got many titles, it stood first for its relation with suppliers, second as organization which examines its relation with suppliers. It was also second for pursuit of excellence, third for a profit potential[237]. Automobile are marked under three brands by the company as shown in Figure 3-7.

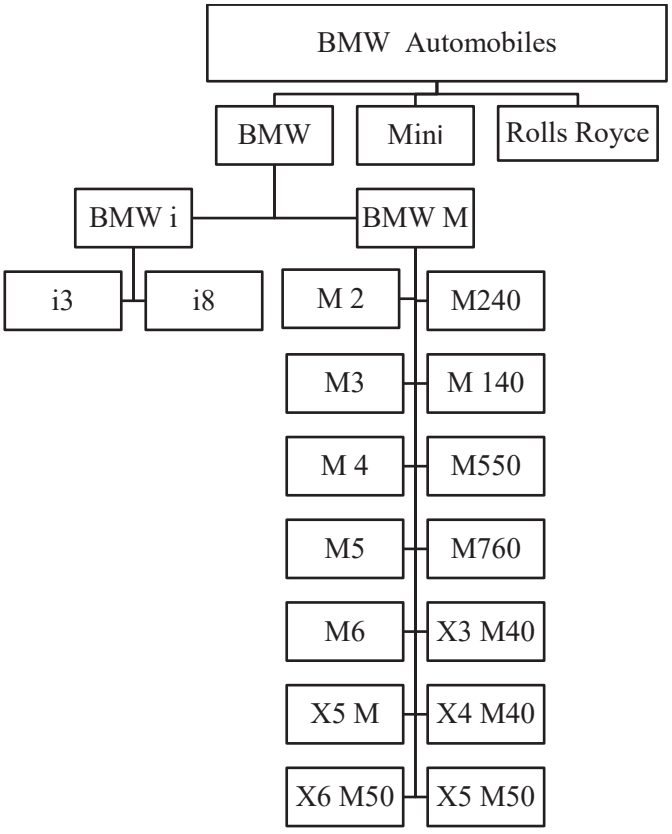

Figure 3-7: BMW AG sub-divisions

[236] http://www.investopedia.com/ask/answers/060115/who-are-bmws-main-suppliers.asp#ixzz4qPKJROAA Seen on May 2016

[237]http://www.supplymanagement.com/news/2012/bmw-tops-ranking-in-supplier-relationship-index Seen on May 2016

BMW AG automobiles are categorized under three main brands, BMW AG, Mini and Rolls Royce. BMW AG brands are further divided into BMW AG I and BMW AG m, which further consist of number of brands.

3.3.1.1 **Policies of Mass Customization**

BMW AG is a pioneer in automotive industry, concerning its mass customization program. It uses highly developed factory automation system, which has flexible production line to develop customized vehicles[238]. Moreover, BMW AG has a program, "Customer Oriented Sales and Production", with focus on mass customization it was launched in 1998. With this sophisticated program, a customized vehicle is built in 12 days while the customers are allowed to make changes even 5 days prior to delivery. Company has better economies of scale than Mercedes-Benz and Volkswagen AG, concerning mass customization[239].

3.3.1.2 **World Wide Production**

BMW AG has 23 plants in 13 different countries worldwide as shown in Figure. About 50% of BMW AG production takes place in Germany at the plants of Leipzig, Munich, Dingofling and Regensburg while 20% of the production takes place in the USA plants of Spartunburg and Rosslyn. The distribution pattern will be further analysed in chapter 4.

Figure 3-8: BMW AG production worldwide

Source: BMW AG market analysis[240]

[238] http://www.industryweek.com/factory-of-future Seen on May 2016
[239] http://idea-space.eu:19001/up/fa23e59ded07adcfb1de0c1317c01a84.pdf Seen on May 2016
[240] https://www.slideshare.net/lorenzilling/bmw-market-analysis-5879711 Seen on May 2016

After getting overview of the company structure, the supply chain structure of the company will be analyzed now, using the structure developed in last section.

3.3.2 Supply chain as a business process

3.3.2.1 **Supply chain strategy models**

BMW AG has a close bonding with many of its supplier, with many suppliers, with many suppliers, it has formed the partnership, but this is not always the case. The suppliers locate close to BMW AG plants in order to provide JIT supply[241]. BMW AG relies heavily on its suppliers for the innovative process and new product development[242]. There are many examples for such relations; e.g., BMW AG formed a partnership with PSA to build next generation four cylinder engines[243]. Moreover, a new working model is established by BMW AG, for the advanced development related functionalities. Under this model, a partnership based on equality in Intellectual property and developmental results has been formed between BMW AG and Continental (unlike conventional supplier model).

3.3.2.2 **Strategy in plant**

BMW AG plants are highly autonomous, number of BMW AG plants in Germany already have driverless tuger trains. The automatic system of BMW AG starts with the customer order and specification. Once the order is placed, the system would determine which factory will build that order, depending upon the availability of the material and location of the customer, after that process the order then automatically trigger the material order from the suppliers[244].

BMW AG use an advanced mySAP system to manage inventories and manage production statues. This system is updates after every three minutes and register production confirmation. Parts which are consumed during consumption are removed from the inventories. This system helps to reduce delivery time for the car. Large suppliers of the company receive the order update through Electronic data interchange (EDI) while the other suppliers have the access to mySap portal. While for the management of inventories, BMW AG sends two types of forecast to the suppliers, long horizon and short horizon. [245]

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[241] http://www.inderscienceonline.com/doi/full/10.1504/IJSOM.2014.060449 Seen on May 2016

[242] https://link.springer.com/article/10.1007/s11747-013-0360-7 Seen on May 2016

[243] http://www.sciencedirect.com/science/article/pii/S0925527316300238 Seen on May 2016

[244]http://automotivelogistics.media/intelligence/bmw-shaping-self-steering-supply-chain Seen on May 2016

[245] http://www.academicjournals.org/journal/AJBM/article-full-text-pdf/90EAD5628698

3.3.2.3 **Supply chain under dynamic environment**

BMW AG has a high flow which must has to be supported by the supply chain. According to BMW AG "30m parts per day move from 1,800 suppliers, i.e. 7,000 sea freight containers per day, and in a year 84m cubic meters across ocean, road, rail and air freight. Around 9,000 vehicles leave BMW AG plants each day on their way to 4,500 dealers in 160 countries".

The planning for this large supply chain is done through BMW AG order-to-delivery system. This system allows customer to customize vehicle and even give customers the option to change the order even before 6 days of production. BMW AG is intended to launch "Connected supply chain" concept, a part of the concept has already been existing in BMW AG plants, to launch the program with full extent BMW AG want logistic providers and supplier to use communication and data that are mutually intelligent. BMW AG has been collaborating with its suppliers on higher level to develop logistics system based upon sensor for logistics equipment and IT system[246].

All the supplies in plants arrive just in time. Thus BMW AG only orders when it needs[247]. However it gives the suppliers forecasts about short run and long run[248]. Moreover, since the space becomes the problem in the plants, BMW AG has used Just in sequence (JIS) technique in some of its plants e.g. Modine plant. This transformation not only has increased the storage area but has also simplified the operations[249] .

3.3.3 Supply chain network

3.3.3.1 **Maintaining a massive relation with suppliers**

BMW AG has 120000 suppliers from 70 countries, with many suppliers BMW AG is having a long partnership terms. To manage this massive relation network, BMW AG has a special department which is responsible for maintaining the relation with the suppliers. Moreover, purchasing and supplier network division along with special departments is responsible for development of sustainable supply chain. Their main purpose is to enable purchaser, supplier and other business partners to integrate different aspects like environmental, social and governance standards more comfortably[250]. BMW AG

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[246]http://automotivelogistics.media/intelligence/bmw-shaping-self-steering-supply-chain Seen on May 2016

[247] https://www.ft.com/content/e09a322e-446a-11e7-8519-9f94ee97d996 Seen on May 2016

[248] http://www.academicjournals.org/journal/AJBM/article-full-text-pdf/90EAD5628698 Seen on May 2016

[249] https://www.computerwoche.de/a/just-in-sequence-statt-just-in-time,1060859 Seen on May 2016

[250]http://www.bmwgroup.com/e/0_0_www_bmwgroup_com/verantwortung/lieferkette/ueberblick.html Seen on April 2017

uses “process consulting approach” with the suppliers in Germany, since they have a long mature relationship. This model does not work however in other countries plants of the company[251].

3.3.3.2 **Control over manufacturing**

Concept of the supply center is used by BMW AG, to move its supplier near the assembly lines. According to this concept, the location is owned by OEM, (Leipzig plant). In this case, BMW AG has developed its own site, while all the logistic providers and the suppliers are tenants in the place. Since the suppliers are close, the late module configuration is possible with Just in time material flow. However, since the site is owned by BMW AG, so it has still enough flexibility to change the suppliers[252]. Since the supplier is like a tenant and not the owner on the site, this gives the OEM, control over the supplier.

If the supplier fails to deliver the JIT goods to the manufacturer, than all the losses incurred by the BMW AG would be liable to the supplier. Moreover the supplier has to inform BMW AG about the buffer stock it has, at regular time intervals[253]. Some of the car seats are still produced in-house, instead of being outsourced, thus to retain expertise. BMW AG has a special team to evaluate the supplier base cost; this helps the company to evaluate what they should be paying to the supplier and also to retain the expertise[254].

3.3.3.3 **Suppliers contribution**

BMW AG has a long history of declining in-house operations, e.g. 45% of the operations were reduced in 2005. BMW AG focused to get in partnerships with the OEMs to produce engines, e.g. an Alliance with PSA Peugeot Citroen was to develop a new line of engines[255]. Thus, supplier’s contribution in the production has increased significantly due to high outsourcing. BMW AG have prioritized outsourcing up to the level that even the assembly lines in Austria were outsourced to Magna International. Even the company is considering the outsourcing of the key core competence of research and development; however BMW AG tries to minimize the risk of outsourcing by maintaining the quality control of the

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[251] Rhodes, E., Warren, J. P., & Carter, R. (Eds.). (2009). Supply chains and total product systems: a reader. John Wiley & Sons.pg 172

[252] Bennett, D., & Klug, F. (2010). Automotive supplier integration from automotive supplier community to modular consortium.

[253] https://www.bmwgroup.com/content/dam/bmw-group wesites/bmwgroup_com/responsibility/downloads/en/2014/140331_IPC_clean_englisch_Status_31.03.2014.pdf Seen on May 2016

[254] http://www.informationweek.com/strategic-cio/enterprise-agility/4-outsourcing-lessons-it-can-learn-from-automakers/a/d-id/1316031 Seen on May 2016

[255] http://wardsauto.com/news-analysis/bmw-outsourcing Seen on May 2016

vehicles under its governance[256]. BMW AG have also outsourced its customized components like car seats for some of its plants. When the order is received, BMW AG delivers the order to the supplier to build the seats according to the selected specification and the order just reaches the assembly line before 90 minutes of final assembly. The suppliers are located near to the assembly lines[257].The focus of the company was to outsource most electronic systems and technologies. To gain this, automaker form more partnerships with the suppliers. The company started looking to the innovators and not only the suppliers[258]. BMW AG have even outsourced the assembling line for some of its international markets. With the globalization, BMW AG has demand in many countries; it is not possible for the company to extend production in all markets. For this reason company has been supplying parts to these markets and then the local manufacturers are assembling them according to local needs. However, to maintain the brand quality, the assembling lines are dictated by the BMW AG. One such example is of the BMW AG market in Egypt[259]. Another bigger outsourcing example from BMW AG was seen in 2016, when automaker outsource production of 5 series model to independent vehicle manufacturer, Magna Speyer in Austria[260].

3.3.4 Supply chain management components

3.3.4.1 **Management methods**

BMW AG has a multi-layered internal management system, which has different level of variations, due to the level of aggregations, e.g. the operating performances are primarily managed at the segment level. While to manage the performance in the long term and to evaluate the strategic issues, various key performance figures are analyzed after regular intervals[261].

Since, BMW AG has outsourced number of parts and functions, thus it has an established team of employees, who are targeted to measure the cost at supply base. This helps BMW AG to estimate the cost of supplier and have a deeper insight into their systems, and set the proper pricing policies[262].

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[256] Clive Reading. (2002). Strategic business planning: a dynamic system for improving performance & competitive advantage. Kogan Page Publishers.pg 77

[257] http://iscltd.com/library/component-outsourcing.html Seen on May 2016

[258]http://wardsauto.com/news-analysis/bmw-outsourcing Seen on May 2016

[259]https://abubakrag.wordpress.com/2012/11/19/bmw-outsourcing-assembly-and-the-modular-industrial-strategy/ Seen on May 2016

[260]http://www.motorauthority.com/news/1106127_bmw-to-outsource-some-5-series-production-to-magna-steyr Seen on May 2016

[261] BMW annual report 2017 Seen on May 2016

[262]http://www.informationweek.com/strategic-cio/enterprise-agility/4-outsourcing-lessons-it-can-learn-from-automakers/a/d-id/1316031 Seen on May 2016

3.3.4.2 **BMW AG work and organizational structure Structures**

BMW AG structure remains unchanged since 2000. But due to changes in the number of strategies the complexity of tasks at different departments has been much higher than before. To manage this, BMW AG has developed best strategy implementation strategies, to get the work done in the timely manner[263]. Structural organization at plant may vary according to the tasks and location. BMW AG has developed a concept of "Plaintively", which is introduced in Business to business (B2B) portal that is specifically designed for employees and suppliers. Suppliers not only contribute with the product but also help for innovation, research and development, production and marketing[264].

3.3.4.3 **Planning and control**

Since 2009, different performance indicators are measured which are used to evaluate the performance of organization accurately. These indicators include economic, societal as well as governance related sustainability performance indicators, which also measures the sustainability of the suppliers, this practice is more profound in purchasing and distribution department of BMW AG I Brand. However because of success of this approach it is now also been transferred to BMW AG I group. Through these performance indicators BMW AG evaluates the sustainability of BMW AG suppliers. Different types of indicators used by BMW AG can be categorized in three main categories, as reporting indicator, control indicator and target indicators. Reporting indicators are monitoring figures which have to be at certain targets, control variable are used for control purposes, and these indicators have implications on BMW AG day to day work[265].

While selecting suppliers, BMW AG have several stages of procurement process, there are also measures at each step that reduces risk factor. Potential suppliers that want to be the supplier of BMW AG must take into account the BMW AG sustainability requirements, when they submit their initial proposal to BMW AG. Procurement processes is centrally controlled and is followed worldwide; even while the selection of local suppliers, Suppliers have to submit initial proposal, in which they should also address use of aluminum. After the proposal has been submitted it is evaluated keeping several

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[263]https://tortora.wordpress.com/2009/11/17/bmw%E2%80%99s-organizational-structure/ Seen on May 2016

[264]https://brainmass.com/business/organizational-structure/organizational-structure-bmw-159035 Seen on May 2016

[265]http://www.bmwgroup.com/e/0_0_www_bmwgroup_com/verantwortung/lieferkette/ueberblick.html Seen on May 2016

standards, it is kept sure that supplier would keep sustainability. To avoid delays BMW AG tries maximum to get supply from local suppliers, this not only reduces transportation time but also the cost. At Spartanburg location almost 80% of the buying was from the local suppliers in 2012[266].

3.3.4.4 **Sustainability in organizational structure**

BMW AG have made supplier sustainability standard, which enlist the principles that must be accomplished by the suppliers, it includes compliance with all internationally recognized human rights laws as well as labor and social standards. In earlier stage of supplier selection it is ensured that the future business partner maintains the environmental and social standards, which BMW AG maintains. The evaluation of supplier is based upon there adherence towards BMW AG Group Supplier Sustainability Standard. Furthermore to ensure the standards contracts with the suppliers includes the clauses which refer towards the principle of UN global compacts and international labor organization. BMW AG ensures that standards are maintained not only to the first tier suppliers but also to the sub tier supplier. BMW AG tries to maintain and support the process of keeping standard. First tier suppliers are at challenge to maintain management system to ensure compliance with BMW AG sustainability requirements[267].

3.3.4.5 **Product flow facility structure**

Recently, automotive companies has started speaking about the importance of logistics, BMW AG is reorganizing the production process through digitalization, in order to connect all of the work flows in logistics. The automation in the order system would help the order itself to decide where it would be built and then it would trigger the material and supply chain. Mobile robots would be used within the plants to deliver the goods, while the driverless trucks would be used to deliver materials[268].

3.3.4.6 I**nformation flow facility structure**

BMW AG is using Level 3 content delivery network (3CDN) system, to accelerate information flow between its headquarter in Munich and its more than 4000 dealers from different parts of the world. Previously, the task was done by DVD bases system, the 3CDN system ensure maximum availability all the times. The dealers can access secure information, can help customers to configure the vehicle and can apply software patches. Depending upon the need, dealer in any part of the world who has

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[266]http://www.bmwgroup.com/bmwgroup_prod/e/0_0_www_bmwgroup_com/verantwortung/lieferkette/beschaffungsprozess.html Seen on May 2016

[267]http://www.investopedia.com/ask/answers/060815/who-are-daimler-mercedes-dai-main-suppliers.asp Seen on May 2016

[268] https://automotivelogistics.media/intelligence/bmw-shaping-self-steering-supply-chain Seen on May 2016

access to DVD based distribution can switch to 3CDN system. To make the connection more direct from the headquarters in Munich, level 3 has provided two fiber optics cables and additional routers in the direct premises of BMW AG headquarters. Moreover, BMW AG and Level 3 have installed "Dense wavelength Division multiplexing (DWDM)" equipment. This has increased the transmission capability[269].

3.3.4.7 **Risk control**

To avoid risks in supply chain BMW AG has a special risk management process, this process was developed more in 2012, it is carried out in three stages, and these stages can be classified as sustainability risk filter, questionnaire and sustainability audits[270] . Details of these stages are as follows:

Step 1: Sustainability risk filter.

This Risk filter evaluates all suppliers of production material, non-production relevant goods and services with regards to the social environmental and governance risk potential. It takes into account supplier's location while measuring risk associated e.g. in certain countries it focuses more on child and forced labor, environmental risks etc. Similarly sustainability risk filter is also used to assess sub suppliers conditions also.

Step 2: Voluntary self-assessment questionnaire

The risk filter forms the basis for the next step in which the supplier submits a voluntary self-assessment questionnaire; suppliers are required to submit a self-assessment questionnaire. This questionnaire assesses the risk profile of the individual supplier. Suppliers are been asked to submit these questionnaire since 2009. This questionnaire is a self-assessment of the supplier, the questionnaire have 27 questions which explore conditions of suppliers regarding specific and individual production facility, it also delivers information regarding International Organization for Standardization ISO 14001, environmental management systems, recyclability in product development, waste disposal concepts and compliance with human rights. Around 3300 suppliers submitted such questionnaire by 2012, if the questionnaire shows that the level of sustainability is middle or low level then BMW AG helps the

[269]http://www.infotechlead.com/mobility/bmw-uses-level-3-cdn-speed-information-flow-28242 Seen on May 2016

[270]http://www.bmwgroup.com/e/0_0_www_bmwgroup_com/verantwortung/lieferkette/risikomanagement.html Seen on May 2016

suppliers to raise the standards. Potential suppliers with known supply sustainability deficits are supplemented by corrective action plans and clauses. This structure ensures that all sustainability requirements are met before services are provided.

Step 3: Sustainability audits.

After the above mentioned procedure, suppliers who are found to be with less sustainability are lead to independent external audits. This method is implemented in 2013, production facilities of the suppliers is accessed by the external auditors and it is checked that whether the suppliers meet the BMW AG standards or not, if the non-compliance is found than the BMW AG works along with the Supplier production facilities to increase the sustainability, moreover if the supplier is found to uncooperative in the process than the business relation may terminates.

Individual cases of non-compliance

There is a supply chain response team, which address the cases of non-compliance with in the sustainability principle, along the supply chain. These ad hoc teams have representatives from the different departments like purchasing, corporate strategy, corporate communication, as well as work council. There were five cases reported to ad hoc team in 2012, the team takes three step approach to the non-compliance cases, first a management of the supplier company have to give a clarification, if still non-compliance is confirmed and supplier is not agree to remove noncompliance than supplier could be banned, in 2012 supply from one supplier was terminated due to this fact. BMW AG have no effect on sub supplier so can only encourage the first tier supplier to maintain the standards along the supply chain management. BMW AG has a long term goal that its standards would be implemented not only to the first tier supplier but also to the sub supplier[271].

3.3.4.8 **Reward structure**

The BMW AG Group has given the Supplier Innovation Award since 2011. Through this award, BMW AG Group hopes to acknowledge and recognize the outstanding innovative performance advances of suppliers. The award is presented in six categories, which are sustainability, emotional experience, digitalization, efficient dynamics, quality, and productivity.

[271]http://www.bmwgroup.com/bmwgroup_prod/e/0_0_www_bmwgroup_com/verantwortung/lieferkette/einzelverstoesse.html Seen on May 2016

Innovation strategies

For the BMW AG Group, the expertise, creativity and innovation of its major suppliers play a crucial role in improving the sustainability of products and processes. In March 2012, the BMW AG Group initiated "ideas competition" focused on sustainability. The goal of this competition was to work together with the supplier to improve sustainability in product and process as well as to increase cost and resource efficiency and customers' benefit.

Ideas or already implemented best practice solutions in the field of environmental protection, economy, and social responsibility are evaluated after concrete criteria such as originality, customers' benefit, innovative strength, improvement in efficiency by the specialty departments. The most promising ideas are further discussed together with the supplier and the best ideas are nominated for the BMW AG Group Supplier Innovation Award in the category "Sustainability"[272].

3.3.4.9 **Training courses for employees and suppliers.**

BMW AG is working along with the suppliers to make supply chain more sustainable and reliable. There are various training program which focuses problems of suppliers, buyers and internal process partners. Apart from working only in the company, BMW AG is working with other industries also to keep supply chain sustainable and keep environmental and social standards within it.[273]

Learning from suppliers

Collaboration with suppliers can be found in many programs. There are forum like learning from supplier, Supplier Innovation Award, Innovation design competition, Training courses for Employees and Suppliers[274]. This forum was introduced in 1990, about 25 suppliers provide best practice case study each year, which helps in innovation and sustainable solution for product material. Suppliers also discuss their standards and ways in which they are maintaining environmental friendly solutions. Such events helped BMW AG to be more innovative. Along with the innovative suppliers BMW AG tries to solve the problems regarding supply chain sustainability[275]

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[272]http://www.bmwgroup.com/e/0_0_www_bmwgroup_com/verantwortung/lieferkette/risikomanagement.html Seen on May 2016

[273]http://www.bmwgroup.com/e/0_0_www_bmwgroup_com/verantwortung/lieferkette/risikomanagement.html Seen on May 2016

[274]http://www.bmwgroup.com/bmwgroup_prod/e/0_0_www_bmwgroup_com/verantwortung/lieferkette/nachhaltigkeit.html Seen on May 2016

[275]http://www.bmwgroup.com/e/0_0_www_bmwgroup_com/verantwortung/lieferkette/risikomanagement.html Seen on May 2016

3.3.5 Summary

BMW AG is world's most profitable automotive company[276]. It has a massive relationship with about 120000 suppliers; company not only focuses on outsourcing but also keep many functions in-house. However for some plants outside Germany even the production lines are outsourced to the reliable partners. Just in time is applied like Mercedes-Benz. However instead of supplier parks, the concept of supplier center is more common, which gives company more control over suppliers manufacturing site. In the case of Mercedes-Benz, it was observed that Mercedes-Benz was deciding the buffer stocks at the supplier base, thus controlling them more inwardly; however BMW AG only keep an eye on the stock levels at the supplier's base, at regular intervals but in the case of non-delivery or late delivery all the losses have to be incurred by the supplier. The analysis can be shortened with these points:

1 Close relation with supplier, not always the partnership
2 A new working model of 50-50 partnership with a supplier, on intellectual property rights
3 Driverless truger train in plants
4 Mysap system manages inventories
5 JIS, step ahead of JIT
6 Order can be changed up to 6 days before delivery due to high developed technological system flexibility
7 Special divisions and departments to manage partnerships and supplier relations
8 Supply center instead of supplier parks, where supplier is tenant on the site
9 Supplier liable for all losses incurred to BMW AG, in case of late or non-delivery
10 High outsourcing, various functions like seat making are both done in-house and by outsourcing
11 Multilayered management system
12 Special team to evaluate the cost at supplier base, this helps company to check and balance the supplier prices
13 Best strategy implementation
14 Three types of indicators used to evaluate performances
15 Focus to get supplies locally
16 Sustainability assurance in the whole supply chain
17 3CDN system to manage information flow within the company
18 Special risk management process with three developed stages
19 Supplier innovation awards to encourage suppliers, since 2011

[276] http://www.chinadaily.com.cn/business/motoring/2017-08/23/content_30997023.htm
Seen on May 2016

20 Ideas completion program

21 Training courses for employees, suppliers and partners

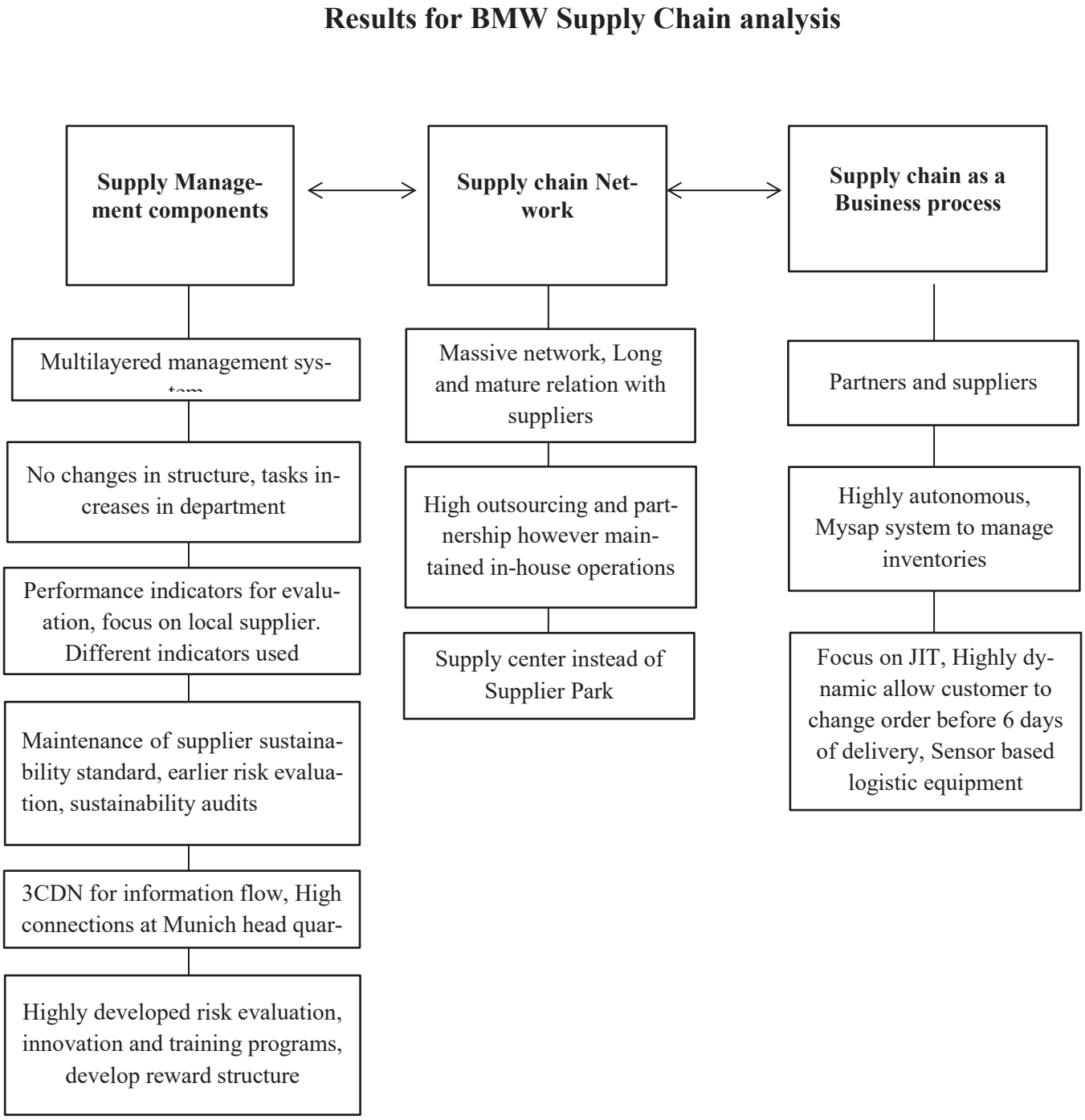

Figure 3-9: Results for BMW supply chain analysis

3.4 Case study analysis of Volkswagen AG

3.4.1 Overview of Company and its system

Volkswagen AG is also a German company and was founded in 1937. According to statistics of 2016, Volkswagen AG group is the largest automobile manufacturer group in world[277]. Largest market of Volkswagen AG is Europe, the second largest is China. The framework settled by Volkswagen AG can be considered as a model to become Automobile giant. It has been named as fourth most influential car company of 20th century[278]. The company division of different models is shown in Figure 3-10.

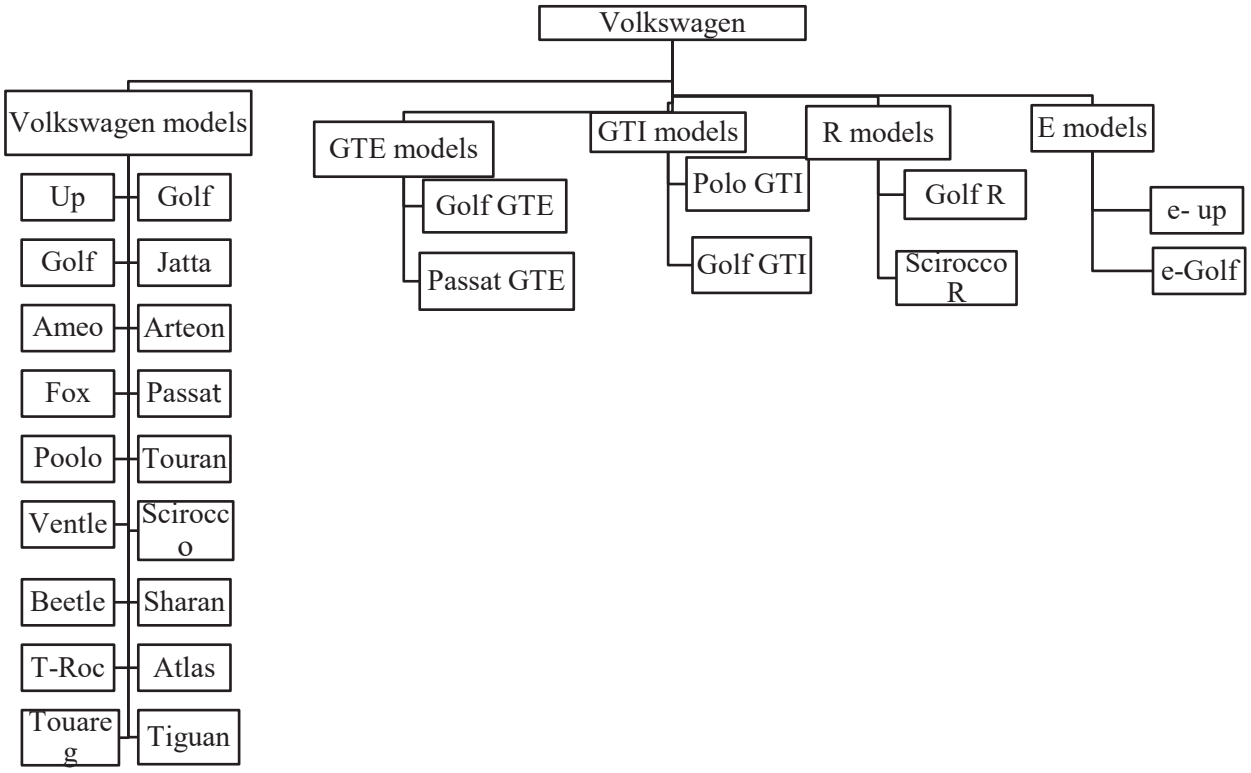

Figure 3-10: Model division in Volkswagen AG

3.4.1.1 Current scenarios

Volkswagen AG has higher vertical integration than any other German automotive company does have; it has a structure, which is comparable to General motors. It has more employees than any other German Automotive company. It has a structure, which is well suited for larger global cooperation. However the scandals faced by the company in 2016, showed the vulnerability in the supply chain of the

[277]Schmitt, B. (2017), https://www.forbes.com/sites/bertelschmitt/2017/06/29/worlds-largest-automakers-toyota-renault-nissan-volkswagen-neck-and-neck/#7ece9a1072fe Seen on May 2017
[278] Cobb, J. G. (1999). This Just In: Model T Gets Award. Revista New York Times, NY, 24.

company[279], moreover the performance of company on different indexes related to supply chain is not satisfactory. It faced many crises in the recent times.

3.4.1.2 **Policies of mass customization**

Volkswagen AG is considered pioneer in developing techniques for mass customization. Volkswagen AG followed strategies of its sister company, Audi, to enhance its customization portfolio significantly[280]. Since the company produces in large volumes, it leads the longer lead times in mass customization. Moreover it has been found that higher product variety in Volkswagen AG has resulted in higher risk situations[281]. However, the trend of mass customization is on rise in the company, with the increase shift on reduction in vertical integration.

3.4.1.3 **Worldwide production**

Volkswagen AG has highly dispersed production pattern as shown in Figure 3-11. Major production sites are in Europe (38 plants) and Asia (18) plants, which account for 53% and 36% of the total production. Further details about production and sales distribution will be discussed in chapter 4.

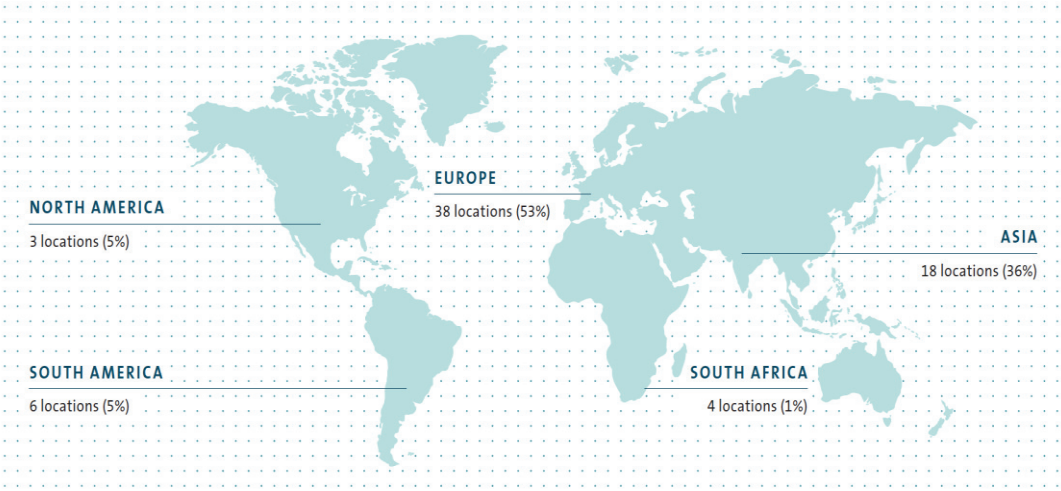

Figure 3-11: Volkswagen AG Production worldwide

Source: Volkswagen AG annual report 2015[282]

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[279] Mcelroy. J (2013), Today's VW Looks Like Sloan's GM, http://wardsauto.com/blog/today-s-vw-looks-sloan-s-gm Seen on May 2016

[280] Friedrich, G. (2008). Mass Customization Services. Department of Management Engineering, Technical University of Denmark.

[281] Can, K. C. (2008). Postponement, Mass Customization, Modularization and Customer Order Decoupling Point: Building the Model of Relationships.

[282] http://annualreport2015.volkswagenag.com/servicepages/filelibrary/files/collection.php Seen on May 2017

After having an overview of company structure supply chain structure is analyzed in this section, with reference to the structure developed in section 3.1 of this chapter.

3.4.2 Supply chain business process[283]

3.4.2.1 **Supply strategy models**

Volkswagen AG has different supply chain strategy than other German automakers; it's more like American General Motors. It has employed more employees than any other automakers, thus has more costs. Company has high decentralized system, least outsourcing and is highly vertically integrated. Volkswagen AG keeps building lot of components in-house. All Volkswagen AG brands are considered as all alone companies, however there is sharing of platforms and purchasing. This system gives company some competitive advantage[284].

In 2005, Volkswagen AG started forming strategic partnership with its long term part suppliers, as company established a task to reduce the purchasing costs of the company, for this reason strategic long term partnerships were formed, , which resulted in economies of scale for both supplier and producer.[285] To decrease the cost in production, several model per platform were built, which result in high cost efficiency[286].

3.4.2.2 **Supply strategy in plant**

Volkswagen AG has implemented number of techniques in plants to increase efficiency. One such example for this innovation is logistics system in plants, which is meant to remove number of errors in the manufacturing system and to cope with high production volumes, this system "Ride along the plat form" was developed by the logistic management team of Volkswagen AG in order to decrease labor, time and effort. This new handling system supports picking up of sequenced parts; it was established in Wolfsburg plant, before its implementation workers had to pull the heavy trolleys when gathering the parts for assembling[287]. Similarly, another plant of the company in Slovakia has smart intelligent logistics concept with efficient networking of the production process and self-governing driverless

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[283] Collins, R., Bechler, K., & Pires, S. (1997). Outsourcing in the automotive industry: from JIT to modular consortia. European management journal, 15(5), 498-508.

[284] How Volkswagen is run like no other car company (2012) https://www.autoblog.com/2012/12/06/how-volkswagen-is-run-like-no-other-car-company/ Seen on May 2017

[285] http://www.autonews.com/article/20051017/REG/510170800/volkswagen-to-form-long-term-supplier-partnerships Seen on May 2017

[286] Brandes, O., Brege, S., & Brehmer, P. O. (2013). The Strategic Importance of Supplier Relationships in the Automotive Industry. International Journal of Engineering Business Management, 5, 17.

[287] http://automotivelogistics.media/news/90311 Seen on May 2017

transport system (FTS), this plant has an attractive work place, thus due to these properties the plant was awarded with the automotive lean Production award in 2011[288].

3.4.2.3 **Supply chain strategies for dynamic environment**

In Volkswagen AG supply chain is considered to be an integrated process, where one department (e.g. purchasing) is linked with another department (e.g. Distribution)[289]. To integrate suppliers further in the production process Volkswagen AG invited all of its global suppliers for the new program known as Future Automotive Supply Tracks (FAST) at Volkswagen AG, which is based upon highly efficient global supplier network. The purpose of the program is to cope with the challenges of modular product designs, high variety and shorter product cycle. According to the program criteria, suppliers who are efficient enough and meet certain criteria can be the part of this program, thus the program targets the best suppliers. The main objective of this program is to optimize investments and make efficient use of resources. The selected suppliers under the FAST program participate with the company on the strategic level; the partners can thus give ideas about innovation in the production[290].

Volkswagen AG has adopted dynamic changes in supply chain quite well, due to programs like FAST. Volkswagen AG has adopted lean production approach well. It is considered as one of the best European automaker to implement lean production[291]. After the financial crises of 2008, Toyota has suffered $1.7 billion dollar loss, at this time Volkswagen AG implement a Modular transversal toolkit (advancement of lean production), this technique has simplified manufacturing processes much more than it was simplified by the benchmarks, set by the Japanese automakers[292] .

3.4.3 Supply chain network

3.4.3.1 **Network size**

In 1983, Volkswagen AG had more than 30,000 suppliers however in 2001 the company had only 4532 suppliers, this was due to the reason that in early 2002 Volkswagen AG liked to work more with fewer

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[288]http://www.leanmagazin.de/best-of/projekte/726-volkswagen-slovakia-erhaelt-automotive-lean-production-award-2011.html Seen on May 2017 Seen on May 2016

[289] Charter, M., Kielkiewicz-Young, A., Young, A., & Hughes, A. (2001). Supply chain strategy and evaluation. London, Centre for Sustainable Design, University College.

[290] http://www.supplychain247.com/article/vw_ready_to_transform_automotive_supply_chains Seen on May 2016

[291] http://planet-lean.com/still-toyota-what-about-volkswagen Seen on May 2016

[292] http://www.planettogether.com/blog/what-toyota-learned-from-vws-manufacturing-process Seen on May 2016

suppliers[293]. Moreover due to financial crises in 2008 company outsourced parts to the supplier[294]. However still outsourcing at Volkswagen AG is lesser than other companies[295].

3.4.3.2 **Control over supply chain**

In the case of BMW AG, it was observed that the contract with the suppliers says that if the supplier fails to deliver the goods in time or not providing at all, all the damages suffered by the OEM would have to be incurred by the supplier, however in the case of Volkswagen AG contract with the supplier has no such clause, in the case of non-delivery, suppliers are not responsible for any loses that are faced by the company, however Volkswagen AG does inform suppliers about their predicted forecast at regular intervals[296]. Regarding the supplier location, mostly the concept more like a supply center has been used by VW to get the supplier near the assembling point, thus the location site is owned by Volkswagen AG group and suppliers are located on it[297].

3.4.3.3 **Suppliers contribution**

Supplier's contribution in the values added of Volkswagen AG group is lesser than of BMW AG and Mercedes-Benz. The Company has a long history of its affinity with in-house operations, in 2004 after facing the financial crises, Volkswagen AG invested in plants for in-house operation of seating assembling, gearbox and exhaust manufacturing; at this time, other major automotive companies were moving rapidly towards outsourcing[298]. Company has highest level of vertical integration, and claims its brand to be "stand alone" company. It has described a model structure for larger global operative automobile companies[299]. After the introduction of the modular platform, across the Volkswagen AG

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[293] Kamp, B. (2015). Examination of dedicated relationships between automotive suppliers and carmakers: evidence on the flagship/5 partners model. Business development: outsourcing, teamwork and business management. Key's for exponential growth, 191. ; Grohn (2002): Interview with Mr. F. Grohn, Member of Volkswagen's corporate management for global and forward sourcing, 21st of March 2002, Wolfsburg; Volkswagen (1981-2002), Geschäftsbericht 1980-2001, Wolfsburg

[294] http://uk.reuters.com/article/us-volkswagen-suppliers-idUKKCN1150OG Seen on May 2016

[295] UK: Pischetsrieder is overlooking the obvious as he faces up to financial problems, (2004) https://www.just-auto.com/news/pischetsrieder-is-overlooking-the-obvious-as-he-faces-up-to-financial-problems_id69302.aspx Seen on May 2016

[296] http://supplynet.autoeuropa.pt/files/order_cond_may2002.pdf Seen on May 2016

[297] Morris, D., Donnelly, T., & Donnelly, T. (2004). Supplier parks in the automotive industry. Supply Chain Management: An International Journal, 9(2), 129-133.

[298] UK: Pischetsrieder is overlooking the obvious as he faces up to financial problems, (2004) https://www.just-auto.com/news/pischetsrieder-is-overlooking-the-obvious-as-he-faces-up-to-financial-problems_id69302.aspx Seen on May 2016

[299] http://wardsauto.com/blog/today-s-vw-looks-sloan-s-gm Seen on May 2016

group purchasing side, supply base was changed with the level of vertical integration (which was already higher than other automobile companies) increased further. Company decide to manufacture most of the components families rather than purchase them, (unlike BMW AG and Mercedes-Benz) this reduces outsourcing to the external partner and thus increasing the number of in-house operation[300].

3.4.4 Supply chain management components

3.4.4.1 **Planning and control**

There is one supervisory board which is responsible for major incorporate decisions. In addition it appoints one board of management[301]. Management at Volkswagen AG is done by different committees at group level; every brand at Volkswagen AG is governed by Board of Management. The board makes sure that every department runs independently and operations run smoothly in between departments[302]. Although company prefers to have a long term plans, but since it is operating globally the focus is to make the plans that could be adjusted, in case of change in global scenarios. Furthermore there are "planning round" process within the group, which focuses to make plans targeting 10 years policy; however the group has discussion every year to cope with the global pace and changes[303].

3.4.4.2 **Sustainability in work structure**

Volkswagen AG group have over 300,000 suppliers until 2016, according to company report to meet the united nations sustainable development goals, company has developed sustainability in supplier relation concept in 2006, and continue to develop it on ongoing bases, furthermore the advance was made in the set program in 2016, when company integrate guideline of Organisation for Economic Co-operation and Development (OECD) "Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Area" into the supplier management approach[304].

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[300]https://www.ukessays.com/essays/marketing/the-supply-chain-management-in-volkswagen-marketing-essay.php Seen on May 2016

[301]https://www.unglobalcompact.org/system/attachments/52841/original/VWAG_SustainabilityReport_2012_english.pdf?1386602621 Seen on May 2016

[302]http://annualreport2014.volkswagenag.com/group-management-report/structure-and-business-activities.html Seen on May 2016

[303]https://www.unglobalcompact.org/system/attachments/52841/original/VWAG_SustainabilityReport_2012_english.pdf?1386602621 Seen on May 2016

[304]http://sustainabilityreport2016.volkswagenag.com/strategy/sustainable-management.html Seen on Jan 2017

Until 2004, the issues of supplier selection criteria and sustainability standards criteria were lacked area of interest and most of the automakers have not identified structured research approaches in their supply chain management related to environmental and social analysis. However, Volkswagen AG took an advanced move in 2004 and in corporation with university of Oldenburg developed an action research project[305]. As a result of the project Volkswagen AG developed a scheme, "sustainability in supplier relation"; gradually the scheme was incorporated into the corporate structure across the group[306]. In 2008, these concepts were further implemented in the general purchasing department[307]. The aim of the program was to develop long term partnership with suppliers and thus to prevent potential supply shortages and to ensure that the quality of goods and services remain consistent. The program has developed a three pillar concept to minimize social environmental and financial risks in the supply chain.

- Early warning system, for minimizing the risks
- Integration of sustainability requirement in the procurement process
- Monitoring of the supply

Multiple cross sectional training sections are conducted. To communicate internally and externally with the supplier, company published its own broacher which is circulated in the stake holders[308].

3.4.4.3 **Production flow & information flow**

The major market of the group is western Europe which has share of 24.4%, the second largest market is central and eastern Europe , 15.4% in south America 19.6 %, north America 4.9% and in Asia pacific 12.2%. VW group has about 100 production facilities worldwide. Since Volkswagen AG operates globally; it prefers to take the supplies locally[309]. The main core market is Europe; the second largest market is China[310]. Volkswagen AG group tried to gain in-house expertise in logistics, and didn't prefer to outsource this department like several others automakers. Even a new board position was established in company to get expertise in in-house logistics in 2006, thus the Group logistics manager has the key responsibility for planning functions and group planning for all the brands and for all the regions.

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[305] Simpson, D., Power, D., & Samson, D. (2007). Greening the automotive supply chain: a relationship perspective. International Journal of Operations & Production Management, 27(1), 28-48

[306] Koplin, J., Seuring, S., & Mesterharm, M. (2007). Incorporating sustainability into supply management in the automotive industry–the case of the Volkswagen AG. Journal of Cleaner Production, 15(11), 1053-1062.

[307] http://supply-chain.unglobalcompact.org/site/article/74 Seen on May 2017

[308] http://sustainabilityreport2014.volkswagenag.com/economy/supplier-management Seen on May 2017

[309]https://www.ukessays.com/essays/marketing/the-supply-chain-management-in-volkswagen-marketing-essay.php Seen on May 2017

Moreover, logistics manager is responsible for maintaining the information and material flow throughout the regions of operation. The brands can have their own operational logistics however there are some processes that have to be standardized across the group. Moreover Volkswagen AG attempted to implement a standardized process to manage the information and material flow for the entire group[311].

3.4.4.4 **Management Methods**

In 2014, Volkswagen AG realigns the management methods, with the aim to prioritize management with broader and global experience. English has been now the official group language. New guideline, focusing to be more globalized has been established, that will become binding after 2021[312]. Volkswagen AG has applied various methods to manage the supply chain; Volkswagen AG has developed several sustainability measures that have to be implemented by the suppliers to their sub suppliers. Due to high number of global suppliers, communication with them is not easy, A B2B portal has been developed for communication with the suppliers, and portal specifies every supplier with the specific number. About 40 million companies are registered in the data base[313]. Volkswagen AG has set all the requirements for the suppliers in the portal. Company is conducting also training courses for the suppliers, specially targeting environmental and social atmosphere. Suppliers, who cannot meet up the Volkswagen AG sustainability standards, are offered special training and programs[314].

3.4.4.5 **Risk Management**

Volkswagen AG uses a country related risk analysis; it is to obtain a clearer picture of social, environmental and human risks in the region. The analysis has shown that there is increase risk in some countries like India, Brazil and china, which do not always comply with the sustainability standards. Thus in a supplier development program special focus is to target these countries[315]. To manage risks at company, the Volkswagen AG is using a COSO (Committee of Sponsoring Organizations of the Treadway Commission) framework. Moreover company is using three line of defense model to save itself from the

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[311] Csizmazia, R. A. (2014). Reconfiguration of Supply Chain at Volkswagen Group to Develop Global. International Journal of Academic Research in Business and Social Sciences, 4(12), 294. ; Elkin, M . (2008). VW Group Unites To Conquer. Automotive Logistics, January - February 2008, p. 22 .

[312] https://www.volkswagenag.com/en/news/2016/12/volkswagen-group-realigns-management-development.html Seen on May 2017

[313] https://www.vwpurchasing.co.za/HowtoBecomeaB2BPartner.aspx Seen on May 2017

[314] http://www.academia.edu/4214614/VW_Responsible_Supply_Chain_Management_Tools_Seite_1_5_Volkswagen_Responsible_Supply_Chain_Management_Tools Seen on May 2017

[315] http://sustainabilityreport2014.volkswagenag.com/economy/supplier-management Seen on May 2017

potential risks. As a result of the emission scandal, the company looks forward to make enhancement in the system.[316]The three line of defense model of Volkswagen AG is as following:

- First line of defense: Operational risk management
  The primary defense of the company against risks comprises of internal control systems and operational risk management at the business units and individual group companies.
- Second line of defense: Systemic risks identification
  The department of group Governance, risk and compliance (GRC) sends standardized surveys on the situation of risks to the suppliers companies and units worldwide; the feedback from the survey is used to detect potential risks in the future.
- Third line of defense: checks by Group Internal Audit
  This system is designed to help the board of management to monitor various divisions and corporate units; one of the key responsibilities of the audit system is to check the risks through early warning systems.

3.4.4.6 **Award structure**

An annual award program has been established to develop trustful relationship with the suppliers. The award winners are assigned on the bases of skills in product quality, innovation strength, development competence and professional project management[317]. In 2017, this award was presented for the fifteenth time to 19 suppliers while in 2016 this award was given to 21 suppliers[318].

3.4.5 Summary

Volkswagen AG is the largest automobile company in the world; its major market is in Europe. The framework settled by Volkswagen AG is considered as the model for biggest automakers. Volkswagen AG has suffered major supply chain issues in 2016; dispute with two suppliers has halted the production in half of the German plants. The main features of the supply chain noted are as follows:

1. Volkswagen AG prefers in-house operations rather than outsourcing,
2. Company has highest number of in-house operations and least outsourcing
3. Partnership with long term supplier has been established since 2005

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[316]http://annualreport2015.volkswagenag.com/group-management-report/report-on-risks-and-opportunities/risk-management-and-control-system.html Seen on May 2017

[317] http://www.autocarpro.in/news-international/volkswagen-awards-21-suppliers-20182 Seen on May 2017

[318]https://www.volkswagenag.com/en/news/stories/2017/06/volkswagen-group-honors-its-best-suppliers.html Seen on May 2017

4. Number of innovative strategies has been established in the plants
5. The “ride along the platform” a new handling system that consist of mobile platform was established, to fast the sequencing and handling of the parts
6. Best European automotive company in implementing lean production
7. Fast VW, a new program established to efficiently utilize resources
8. Volkswagen AG likes to work with part supplier
9. Company has market all over the world, and has also production plants in every corner
10. Logistics system is not outsourced
11. Most of the processes are standardized all across the brands
12. B2B portal has been developed, to have faster and easy access of suppliers to the OEM
13. Country related risks are evaluated and special policies are devised for the countries with high level of risks
14. Three line of defense model has been developed to manage risks
15. An award system has been devised since 1998
16. No control measures to manage inventory at supplier
17. In case of non-delivery, supplier is not responsible for the losses of Volkswagen AG
18. Since has less dependence on suppliers, thus has least expertise in management of relations with suppliers

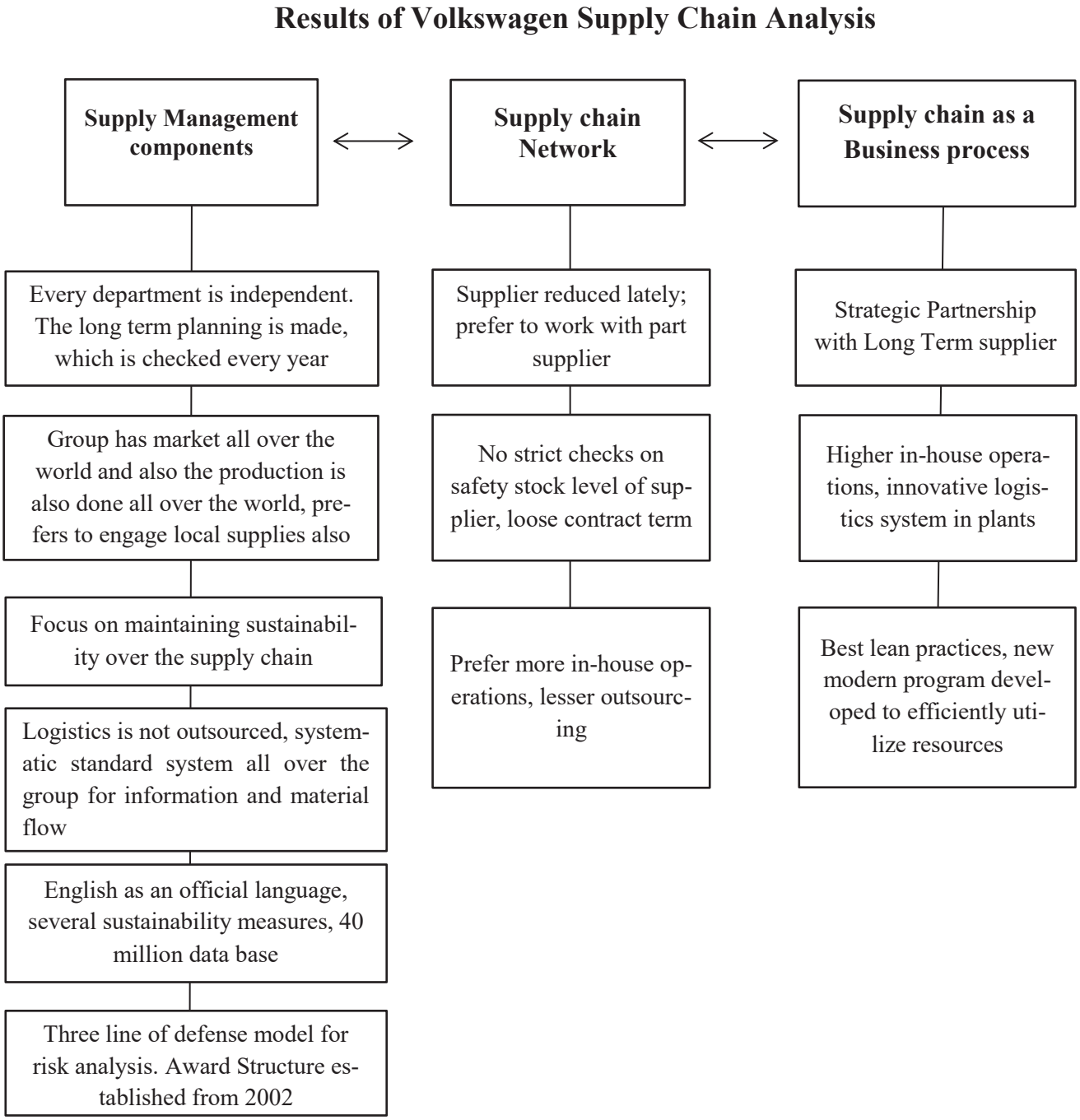

Figure 3-12: Results for Volkswagen supply chain

3.5 Comparative analysis and results

In this chapter, a framework is developed to analyze the nature of supply chain in section 3.1. This framework has been used to investigate supply chain of all three companies. The detail of the nature of the supply chain of each of the company has been established, differences and similarities are also highlighted. The question arise that which of these practices are efficient and more suggestible. It is find out that more or less Volkswagen AG has different supply chain structure than Mercedes-Benz and BMW AG, as this company focuses more on in-house operation while the other two have great affinity for outsourcing. Before getting to the conclusion, it is important to see that which of these companies has better supply chain practices. For this purpose in this section critical analysis of the supply chain of these companies would be carried out on bases of [performance on surveys, number of incidents happened, review of suppliers (through indexes) and other problems. Based on this final conclusion of the chapter would be deduced.

In order to analyse the supply chains of these companies critically, it will be investigated that which of these company have best supply chains relations and policies, based upon the results of indexes and the number of incidents happened.

3.5.1 Performance on surveys

European survey

Supplier relation index (SuRe) in Europe is used to investigate automotive company's relation with the supplier. The relation is assessed on the bases of questionnaire, which has 29 questions about five different categories of trust, profit potential, Pursuit of Excellence and Outlook. For developing this index, suppliers are asked to give response about the Automotive Company on 29 metrics, which are about both economical, and relationship related[319].

[319] http://europe.autonews.com/assets/PDF/CA80160620.PDF Seen on May 2017

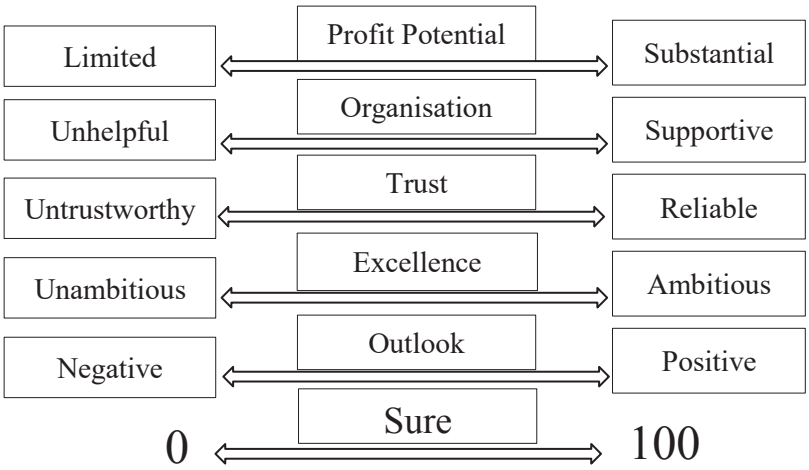

Figure 3-13: Categories in Sure index

Source: Europe Autonews [320]

The survey is published annually, in quantitative measure by OEM-Supplier relations survey. Any value greater than 700 is considered outstanding, while below 400 is considered highly critical. Since the survey includes the response of 50 suppliers from world's top 100 suppliers. Moreover, about millions of managers working in automotive suppliers companies and directly in touch with automotive companies contribute into the survey directly. It is considered very authentic in automotive industry. The scale of the Index is from 0-1000, 0 considered lowest and 1000 is considered maximum[321]. The detailed description of values of SuRe index is shown in table 3-1.

Values	Description
0	Lowest possible value
<400	Critical area
<450	Lower threshold
≈550	Average
>650	Somewhat satisfactory
>700	Outstanding achievement
1000	Highest possible value

Table 3-1: SuRe Index values description

[320]http://europe.autonews.com/assets/PDF/CA80160620.PDF Seen on May 2017
[321]http://europe.autonews.com/assets/PDF/CA80160620.PDF Seen on May 2017

After analysing sure index for three companies, we compare the value of the index in the table 3-2.

Company	2012	2013	2014
BMW AG	617	627	627
Mercedes-Benz	606	621	617
Volkswagen AG	531	561	525

Table 3-2: Sure Index for three companies

Source: SuRe Index[322]

As shown in table 3-1 BMW AG maintained first position in all three years, while Mercedes-Benz (which has almost the same policies) remained behind with just few numbers, while Volkswagen AG has quite low performance on the index, showing the lack of trust and relationship with the suppliers.

North American survey: A special survey, knows as PPI, in North America, carries out study since 1990 to analyse the relation between OEM and first tier supplier. This survey has started analysing German automotive companies since 2010. This study carries out annual Working relation Index (WRI) that is considered as a benchmark for supplier working relation in automotive industry[323]. This index actually quantifies the qualitative working experience of the supplier with the buyer (automotive company). The working model of WRI is shown in Figure 3-14, it comprises of five major variables, there are two or more questions in the survey related to this variable. The values of each variable depend upon the response from the supplier.

[322]http://news.ihsmarkit.com/sites/ihs.newshq.businesswire.com/files/press_release/file/102714_IHS_Automotive_OEM_Supplier_Relations_Study_Media_Version_Final.pdf Seen on May 2016

[323] http://www.prnewswire.com/news-releases/oem-supplier-relations-study-shows-strong-gains-for-toyota-and-honda-with-ford-nissan-fca-and-gm-falling-well-behind-300084605.html Seen on May 2016

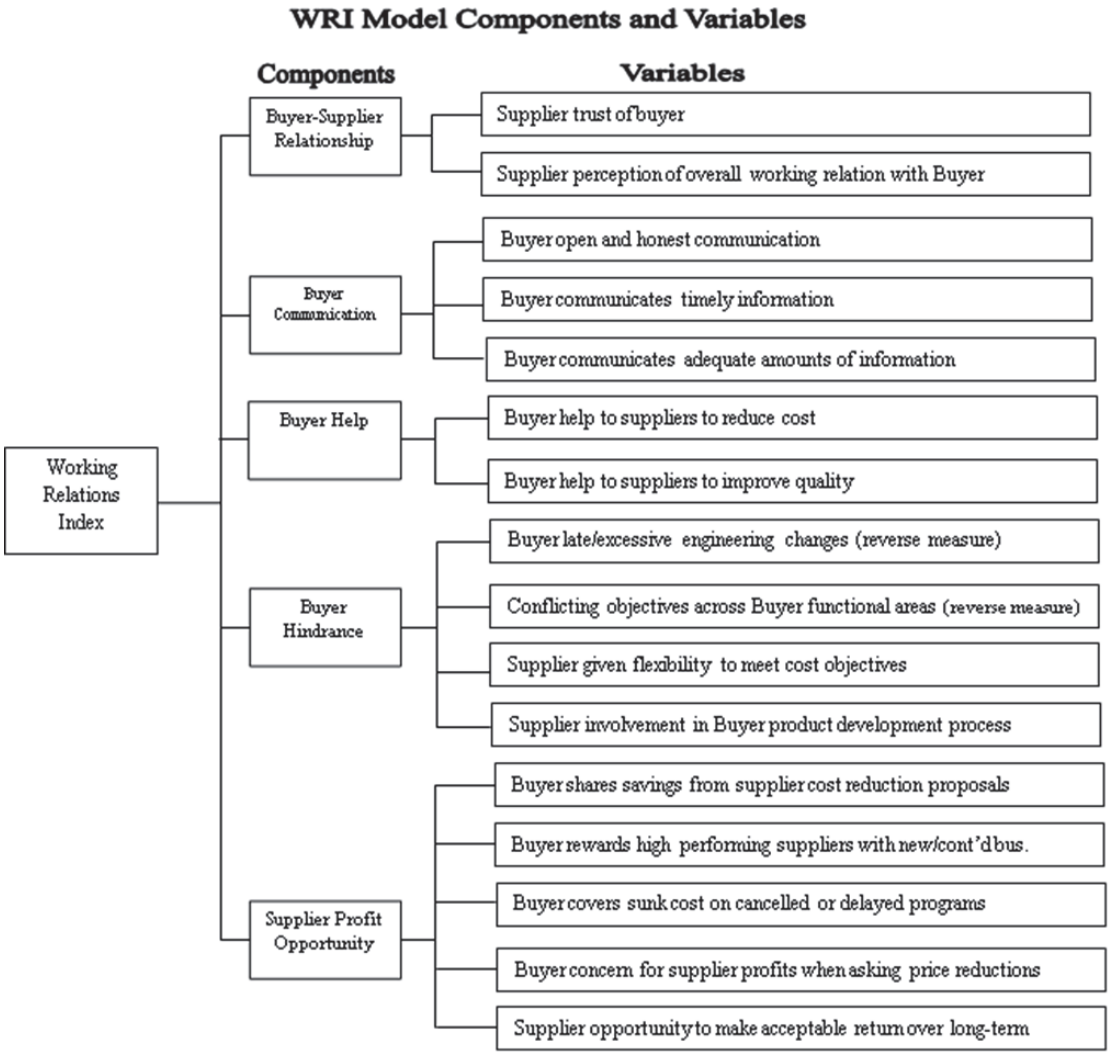

Figure 3-14: WRI model components and Variables

Source: ppi1[324]

The response on the variables mentioned in Figure 3-7 are than evaluated on the scale from 0-500, which is described in detail in Figure 3-8.

[324] http://www.ppi1.com/working-relations-index/

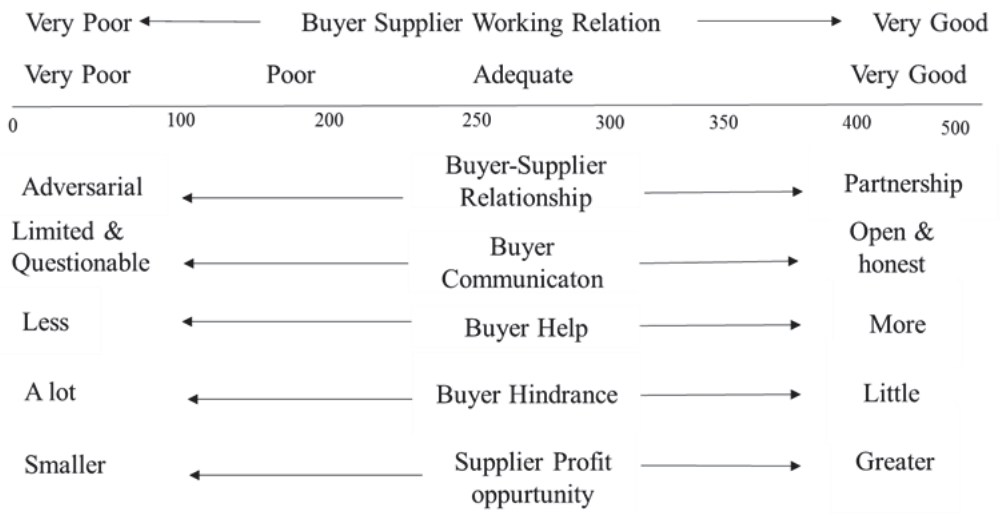

Figure 3-15 : Working relation index methodology and scale
Source: ppi1[325]

The performance of three German companies according to WRI index is shown in table 3-3. The results from this index are same as from the SuRe index, BMW AG not only performed best in European automotive companies, but also in the world. Mercedes-Benz also showed high performing number, however this Index categories in the category of the lowest performance. Therefore the supply chain relations in the Volkswagen AG are not efficient and need high modifications.

Company	2013[326]	2014[327]	2015[328]
BMW AG	307	311	346
Mercedes-Benz	300	227	-
Volkswagen AG	247	181	220

Table 3-3: WRI Index
Source: PR newswire[329]

[325] http://www.ppi1.com/working-relations-index/ Seen on Sep 2017
[326] http://www.prnewswire.com/news-releases/2013-annual-oem-supplier-study-shows-automakers-lack-of-focus-has-stalled-improvements-in-supplier-relations-207165371.html Seen on Sep 2017
[327] http://www.ppi1.com/wp-content/uploads/2014/05/2014-WRI-Press-release-05-12-14-FINAL.pdf
[328]http://www.prnewswire.com/news-releases/oem-supplier-relations-study-shows-strong-gains-for-toyota-and-honda-with-ford-nissan-fca-and-gm-falling-well-behind-300084605.html Seen on Sep 2017
[329]http://www.prnewswire.com/news-releases/oem-supplier-relations-study-shows-strong-gains-for-toyota-and-honda-with-ford-nissan-fca-and-gm-falling-well-behind-300084605.html Seen on Sep 2017

3.5.2 Incidents

1. In January, 2017 fire broke out at plant of Recticel Internationals, Recticel Internationals was the major supplier of various tier 1 suppliers, such as Magna International, Johnson Controls, Faurecia, International Automotive Components (IAC), Visteon Corporation etc. The automotive companies that were affected were BMW AG, Mercedes-Benz and Volkswagen AG. The measures were taken to get supply from the alternative plants[330]
2. BMW AG faced production interruption in January 2017, when its long trusted supplier, Robert Bosch GmbH was unable to supply BMW AG with sufficient number of steering gears. According to Robert Bosch GmbH, the problem was caused by an Italian tier-2 supplier. BMW AG asked Robert Bosch GmbH for all the compensation of its losses. However, the two companies worked together to minimize the impact[331]. BMW AG had to stop the production of series 1,2,3,4 due to lack of parts. Assembling was halted for weeks[332].
3. In august 2016, Volkswagen AG got into dispute with its two suppliers for car seats and cast iron (for gear boxes). This was apparently a dispute of a giant company with two apparently small companies, but this dispute has revealed the biggest discrepancy in the modern supply chain. This dispute halts production level in half of the plants in Germany. The dispute has affected 6 factories in Germany, and around 28,000 employees[333], the problem shows that power is not only with the size but with the monopoly too, this scandal one of the biggest discrepancy in the supply chain, relying on the few suppliers. Since company has no alternative supplier in the short time so the production was halted causing millions of loss to VW. After this incident Volkswagen AG considered to analyze its procurement strategy[334].

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[330]http://www.autonews.com/article/20170131/COPY01/301319959/psa-halts-3008-production-after-supplier-plant-fire Seen on Sep 2017

[331] http://www.finanznachrichten.de/nachrichten-2017-05/40832185-bmw-car-production-affected-due-to-supply-problems-020.htm Seen on Aug. 2017

[332]BMW halts production as Bosch fails to meet supply needs, (2017) http://www.supplychain-dive.com/news/BMW-production-halt-Bosch-supplier-shortage-parts/443949/

[333] https://www.theguardian.com/business/2016/aug/23/vw-settles-dispute-which-stopped-output-at-half-of-german-plants Seen on Aug. 2017

[334] https://www.cips.org/supply-management/news/2017/may/supplier-delays-stall-bmw-production/ Seen on Aug. 2017

3.6 Conclusions

In this chapter, we developed a framework and used it to compare supply chain of three automotive companies; the comparison has showed us some major differences in policies, the attitude and relation towards suppliers and management of logistics policies.

Comparison of the companied showed that more or less the structure to manage the supply chain in Mercedes-Benz and BMW AG is very much comparable. Along with the focus on modularization, supplier parks and outsourcing etc. these companies has developed special expertise to manage their relations with suppliers. Although the main features are much comparable in these two companies, but the nature of relationship with the suppliers is different. It was observed that more or less, Mercedes-Benz have high contract conditions and thus dictated the suppliers on locations, safety stock levels etc., with this suppliers may feel unnecessary burden, while BMW AG treated supplier much as a partner, and developed indirect clauses to control suppliers (in case of non-delivery all losses are suffered by supplier).

At Volkswagen AG, supply chain strategy is completely different from BMW AG and Mercedes-Benz. As the companies' focus is to keep most of the operations in-house rather than outsourcing, so it does not have high dependence of suppliers. Due to less dependence, its relation with suppliers is also quite different, in its recent dispute with the supplier, the company's behavior towards the supplier was not appropriate as it was on the extent of controlling their suppliers and may even cross the line towards supplier bullying, it could be because of the reason that this major cooperation's knew their important value, In this particular case Volkswagen AG break the contract with the supplier, when the supplier has already made amendments in the plants for the new contract and Volkswagen AG refused to pay any reimbursement to the supplier, although halting supplier has also damaged the supplier but they were pushed to the extent to stop the supply[335].Such behavior has resulted in the loss of trust from the supplier, which is also elaborated in the earlier section.

Major policies in terms of supply, has resulted in different kind of producer-supplier relations, the differences in the policy of all three companies is shown in table 3-4. Regarding the logistics policy, it is observed that BMW AG and Volkswagen AG have not outsourced logistics, while Mercedes-Benz has outsourced logistics in some of its plants.

[335]https://www.forbes.com/sites/katevitasek/2016/08/27/vws-supplier-dispute-shines-more-light-on-power-play-practices/#7945fe8b3755 Seen on May 2016

	Mercedes-Benz	**BMW AG**	**Volkswagen AG**
Operation preference	Outsourcing	Outsourcing	In-house, Less % of outsourcing
Supplier relation	Strong relations with supplier Strong control, decide inventory at supplier Supplier parks, developed by the supplier near production site of OEM	Close relation, mostly partnership Keep an eye on safety stock at supplier, not deciding it Supplier center, developed by OEM near the production site of OEM Supplier are liable for all the loses, in case of non-delivery Special training programs for the suppliers	Less partnership No check on safety stock level at supplier site Supplier center, developed by OEM near the production site of OEM Supplier are not liable for the loses, in case of non-delivery Bullying behavior is observed with suppliers
Logistics system	Outsourced in some of the plants	Logistics is not outsourced	Logistics is not outsourced
Risk evaluation	Risk management department Evaluate early risks Development of measures to avoid the risks in future	Developed a special process for risk assessment Three stages of risk filters All the departments have representation in risk assessment	Three line of defense model to control risks
Surveys performance (supplier relation related)	Near best	Regarded best	Lowest rank

Table 3-4: Differences in policies preferences in three cases

The major difference in the policies has resulted in different results for the companies. The comparison of the different indexes in the last section has showed that what is the strength of the company in dealing with the suppliers or in other words how much suppliers are satisfied from these companies.

As the Results from SuRe survey shows that BMW AG has the highest level of relation with supplier persistently, BMW AG not only leave behind its German competitors but also top the whole automotive industry by scoring the highest benchmark while the Volkswagen AG has been considered as worst in handling relation with the suppliers. The results from the WRI are also portraying same as SuRe survey, BMW AG tops the industry in 2013 and 2015 while it leads the German brands in all the considered years. Volkswagen AG, on the other hand is worst in relations with suppliers. Therefore, the policy at BMW AG has resulted towards the best level of relationship with the supplier. Similarly, Volkswagen AG is not only on the bottom of chart in European automotive companies but also among other important American and Japanese brand. GM also follows the same pattern as Volkswagen AG. Since Volkswagen AG has lesser dependence upon the supplier, thus company has still not gained the level of expertise needed to manage an extensive relationship. BMW AG has treated supplier on equivalences base like a partner, however it has developed strict clauses in the contract, which enables the company to manage the supplier indirectly.

Moreover, the analysis of incidents happened has showed that high dependence on suppliers have affected all three automakers on number of times. Although automotive companies have managed the tier 1 supplier quite well (not in case of Volkswagen AG) but the tier 2 suppliers are still not that compatible and high dependencies in the supply chain have interrupted the production many time, mostly due to tier 2 suppliers. Most of the risk control management at OEM is for the first tier supplier and not the second tier supplier.

Furthermore, it is observed through analysis that in the modern production system, automakers has reduced number of suppliers drastically in order to make supply chain relations smoother and simpler; this has caused monopoly to the suppliers. Suppliers, with fewer competitors in the place, find themselves in the stronger position. If one company is the sole supplier of the car seat, they know their power. This happened in VW scandal. It was not possible for the OEM to find the alternative supplier quickly. Moreover, since modern production is based on precision and individuality, thus it was not possible to fit another part from different supplier. Moreover, manufacturing firms nowadays, hold inventory stock for just few days, in some cases for just few hours, in such cases supplier promises to have regular deliveries, but if there is a dispute with that single supplier or if some emergency event takes place with that supplier, then the situation can become problematic. In such cases, the OEM

would be facing a big trouble. Like in the case of Volkswagen AG which had to halt half of its production in Germany[336].

[336]https://spendmatters.com/uk/volkswagen-supplier-dispute-supply-chain-good-practice-may-contributed-problems/ Seen on Aug 2017

4 Panel analysis of supply chain strategies

In the previous chapter, results are developed on the on the basis of qualitative analysis. To further the elaborate issues a panel data analysis would be conducted on the same three companies in this chapter. Some policies, like the management of inventories, supply chain distribution and downstream issues could be tackled more directly with the help of quantitative analysis. This chapter analyze that how some important tools could enhance supply chain efficiency under mass customization. This issue is addressed as second research question of the study.

The chapter is divided into three parts, firstly a model would be developed in section 4.1, secondly the data will be determined that could be used to evaluate the model and finally in third section the model is implemented and results are obtained.

4.1 Introduction to panel data analysis

Panel data analysis is considered to be one of the most efficient analyses of recent times. It has property to combine cross sectional and time series data, so Panel data analysis allows studying a particular subject on multiple grounds i.e., periodical and cross sectional[337]. It offers variety of estimation methods; the combined panel data matrix includes time series for each cross section in the data set[338]. It is different from cross sectional or time series data, in a sense that it has double subscripts with its variable, one is representation of time and one for cross section[339].There are several other points on which panel data is different from cross sectional and time series data; they can be summarized as follows:

- It allows broader source of variation, so it provides more efficient estimation
- More information is outsourced to the reader
- It allows to investigate the dynamic behavior of parameter

4.1.1 Why panel data analysis

The common problem with the time series data is availability of data, since the efficient time series analysis requires data set of up to 30 years which leads to problems. As the data of most recent phenomena are with limited number of years, so the time series analysis with small number of observations lead to insignificant t-test and f-test ratios. Panel data sort this problem as due to cross sectional data the number of observations increases. Another benefit of using panel data analysis for this study is that

[337] Yaffee, R. (2003). A primer for panel data analysis. Connect: Information Technology at NYU.
[338]Asteriou, D., & Hall, S. G. (2015). Applied econometrics. Palgrave Macmillan
[339] Baltagi, B. (2008). Econometric analysis of panel data. John Wiley &Sons.

time series analysis allows to investigate one cross section at one time, thus it is with limited scope as it does not allows to consider variations among the firms in the industry. The cross section data on the other hand, just allows considering variation among the firms; it does not allow considering variation along the time[340]. So these problems lead us to choose panel data analysis, which has combined features of both panel and cross sectional data. There are several advantages of using panel analysis in this case[341], it can be summarized as follows:

1. Model parameters inference is more accurate, since this panel data consist of more degree of freedom and sample variability than cross section data (which is for one year) or time series data (with one cross section). This improves the efficiency of economic parameters[342]. Complexity of firm behavior can be captured with greater capacity[343].
2. Panel data allows controlling the impact of the omitted variables. Omitted variables sometimes may affect the results from the model; however with the panel analysis the data contain information on both intertemporal dynamics and individuality of the entities, and this allows controlling the effect of unobserved or omitted variables.
3. Since this analysis generates predictions by pooling data instead of generating predictions using data on individual firm in question, thus the predictions are more accurate. Panel data provides availability to learn the behavior of one firm while observing the other. Thus it is possible to observe individual behavior more accurately, by supplementing observation from the data on others[344].

4.1.2 Panel data structure

Panel data set generally includes cross sections and for each cross section the observations are spread over period of time[345]. For example if $Y=f(x_1, x_2)$ then the information for these variables will be collected across cross sections (firms, countries, groups etc.) over some period of time, e.g. for 10 years

[340] Asteriou, D., & Hall, S. G. (2015). Applied econometrics. Palgrave Macmillan

[341] Hsiao, C. (2007). Panel data analysis advantages and challenges. Test,16(1), 1-22.

[342] Hsiao, C. (2007). Panel data analysis advantages and challenges. Test,16(1), 1-22; Hsiao, C., Mountain, D. C., & Illman, K. H. (1995). A Bayesian integration of end-use metering and conditional-demand analysis. Journal of Business & Economic Statistics, 13(3), 315-326

[343] Hsiao, C. (2007). Panel data analysis advantages and challenges. Test,16(1), 1-22.

[344]Hsiao, C. (2007). Panel data analysis advantages and challenges. Test,16(1), 1-22.; Hsiao, C., T.W. Appelbe, and C.R. Dineen (1993), "A General Framework for Panel; Hsiao, C., Mountain, D. C., Chan, M. L., &Tsui, K. Y. (1989). Modeling Ontario regional electricity system demand using a mixed fixed and random coefficients approach. Regional Science and Urban Economics, 19(4), 565-587.

[345] Yaffee, R. (2003). A primer for panel data analysis. Connect: Information Technology at NYU.

from 2000 to 2010. The whole set can then be investigated via panel data estimation through fixed or random effect.

4.2 Model development

To investigate the supply chain issues under mass customization via Panel data analysis, firstly there is a need to develop a concrete model. Therefore, in this section a model based upon analysis of literature is developed. The model developed in this section has already being established and published in a paper[346]. Since the analysis is based upon the influences of different factors upon the supply chain efficiency under mass customization, so firstly a measure would be developed to interpret supply chain efficiency under mass customization (dependent variable). After this we would determine the factors that could impact supply chain efficiency under mass customization (independent variables). In this regard, the impact of distribution of supply chain, inventories policies and downstream issues will be discussed.

4.2.1 Efficiency of supply chain under Mass customization

The specific measures for supply chain evaluation will help to analyse efficiency more accurately[347]. With the growing importance of supply chain management in the modern production, literature has emphasized on the tools that are used to evaluate supply chain efficiency. Quantitative measures are preferred over qualitative measures as the later are vague and complicated to utilize, moreover the data is normally available for numerical measures[348]. Financial, non-financial as well as operational measures can be used in this regard[349]. Financial measures have crucial importance in this regard, as it can help for strategic decisions and external day-to-day reporting[350].

Literature shows that there is lesser work done to describe a measure for measuring supply chain efficiency, however, few studies highlight the importance of the fact and describe tools to evaluate supply

[346]Khan, A., & Haasis, H. D. (2016).A Framework for Supply Chain Efficiency Evaluation of Mass Customized Automobiles. World Academy of Science, Engineering and Technology, International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering, 10(5), 1454-1458.
[347]Chen, I. J., & Paulraj, A. (2004). Towards a theory of supply chain management: the constructs and measurements. Journal of operations management, 22(2), 119-150.
[348]Beamon, B. M. (1999). Measuring supply chain performance. International journal of operations & production management, 19(3), 275-292.
[349]Gunasekaran, A., Patel, C., & McGaughey, R. E. (2004). A framework for supply chain performance measurement. International journal of production economics, 87(3), 333-347.
[350]Gunasekaran, A., Patel, C., & McGaughey, R. E. (2004). A framework for supply chain performance measurement. International journal of production economics, 87(3), 333-347; Maskell, B. H. (1991). Performance measurement for world class manufacturing: A model for American companies. CRC press.

chain efficiency. Depending upon the area of focus, three types of measures can be used to investigate supply chain efficiency; 1) output measures, 2) resource measures and 3) flexibility measures. Resource measures and output measures are most widely used measures while flexibility measures have limited scope. Profit is a type of a measure that takes into accounts both resource and output measure. It gives broader overview as it takes into account both sales and cost. Therefore, using profit as a measure can give a broader prospect; it can tell us how different variables are influencing not only supply chain but also the financial performance of company. Furthermore, by taking profitability as a measure to investigate the supply chain management, we can also see how different variables are influencing company's financial performance[351]. Due to the mentioned arguments, profit would be used as a measure to investigate the efficiency of the supply chain; this has given us a broader prospect. The details on the data collection method on these variables would be given in later in this chapter.

4.2.2 Variables effecting supply chain efficiency

Although there are lot of planning and decision that affect supply chain efficiency, however, in this section major issues that influence supply chain on larger scale would be discussed. Successful supply chain management under any production processes depends mainly upon the Inventory planning control process and the Distribution process[352]. Another important aspect important in supply chain management, especially with the aspect of mass customization is that how well the customers are interacted about the possible combinations, its benefits and its issues. Thus, it is important to take the efficiency of producer/buyer relation also, when we are undertaking supply chain under mass customization[353]. So, the mentioned issues will be explored, to develop a model. Thus critical issues, which will be figured out with the model are

- Inventories
- Distributional planning
- Issues in downstream supply chain

[351]Beamon, B. M. (1999). Measuring supply chain performance. International journal of operations & production management, 19(3), 275-292

[352]Uzorh, A.C.; Innocent, N.: Supply Chain Management Optimization Problem. The International Journal of Engineering and Science (IJES) 3 (2014) 6, pp 1-9

[353]Khan, A., & Haasis, H. D. (2016). Producer–buyer interaction under mass customization: analysis through automotive industry. Logistics Research, 9(1), 17.Patterson PG, Johnson LW, Spreng RA (1996) Modeling the determinants of customer satisfaction for business-to-business professional services. J Acad Mark Sci 25(1):4–17

4.2.2.1 **Inventories planning**

Crucial decisions

Inventory management is an important tool to achieve supply chain efficiency; however, Inventory management is a crucial decision for the firm as keeping it higher leads to financial losses while keeping it too low can make the OEM vulnerable to more risks.

It has been find out that with the improvement in the supply chain and technologies, the progress in Just-in-time is increasing. Thus, the raw material and work in progress inventories are declining with time, the sample from US industry suggest that this advancement in technologies and supply chain techniques does not eliminate the risk factors associated with low inventories[354]. The importance of mitigating the operational risks with the help of suitable risk control strategies is a crucial point, which is best possible with inventories control management, given the high cost associated with inventories, it has also been regarded as inefficient tool to manage risks[355]. However, it is less expensive to hold inputs than to hold the finished product so firm may decide to increase the level of inventory, as the later include more value[356]. It was estimated that around £6 billion could be saved in Europe by eliminating finished vehicles stock from Europe in 2001. When the stock is held at the highest value (finished products), which is further discounted in order to sell, it causes a penalty cost in the distribution, if such stocks are minimized it would have resulted in the additional £2.5 billion annual profit[357].

Unpredicted demand in Mass customization

Mass customization operational companies are focusing to maintain inventories low. However, high product variety and unpredicted demand can create a complex environment for inventory management. Since under mass customization customer is allowed to tailor product from large set of options, this

[354]Bianco, M. (2015). Flexibility and firm value: the role of inventories (Doctoral dissertation, alma).:Chen, H., Frank, M. Z., & Wu, O. Q. (2005). What actually happened to the inventories of American companies between 1981 and 2000?. Management science, 51(7), 1015-1031.0

[355]Bianco, M. (2015). Flexibility and firm value: the role of inventories (Doctoral dissertation, alma).: Manuj, I., & Mentzer, J. T. (2008). Global supply chain risk management strategies. International Journal of Physical Distribution & Logistics Management, 38(3), 192-223.

[356]Waller, M. A., Dabholkar, P. A., &Gentry, J. J. (2000). Postponement, product customization, and market-oriented supply chain management. Journal of Business Logistics, 21(2), 133.

[357]Holweg, M., & Miemczyk, J. (2002). Logistics in the "three-day car" age: Assessing the responsiveness of vehicle distribution logistics in the UK. International Journal of Physical Distribution & Logistics Management, 32(10), 829-850..′:ICDP (2000), Fulfilling the Promise: Is there a Future for Franchised Car Distribution?, International Car Distribution Programme

leads to increase in the variety, such high product variety causes risks in inventory forecasting[358]. If the forecast is too low then in such case if the actual demand rise then the producer might not be able to produce, or if the forecast is too high but the actual demand is low then producer have to face high inventory cost.

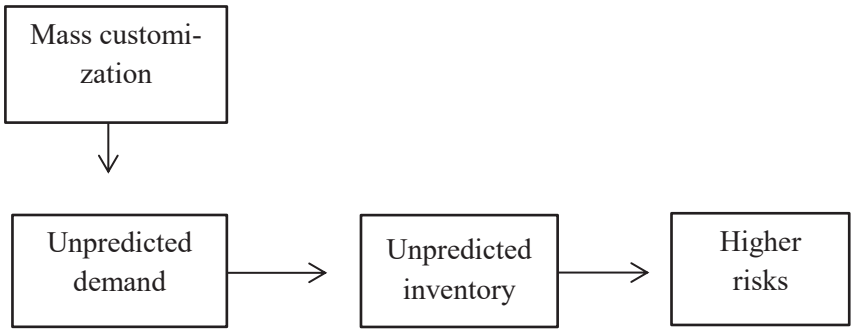

Figure 4-1: Inventory risk management under mass customization

Low inventories approach

To overcome this problem of inventory forecasting, companies (undertaking mass customization) have moved towards JIT[359]. Nowadays, most of the automobile companies (carrying mass customization) are implementing JIT system to reduce cost. These low levels of inventories are only possible through quick exchange of information through all stakeholders[360]. It is observed that these low inventories put pressure on the upstream or low stream supplier, as it is preferred to provide customers the product in shorter time. As a result, the pressure in the niche supply chain also increases. However, since the individual customer demand is highly variable but the semi produced products or demand of parts by company is quite low, it makes sense to keep the inventories at substantial level to meet the uncertainties and flexibilities in the system and thus maintain low lead times[361]. Production system under mass customization are controlled at decoupling point, this is the point in production system where the inventories are held, these inventories can be semi-finished products, parts or pure raw. The higher the

[358]Berman, O., & Sapna, K. P. (2002). Optimal service rates of a service facility with perishable inventory items. Naval Research Logistics (NRL), 49(5), 464-482.
[359]Kobayashi, M., Tomino, T., Shintaku, J., & Park, Y. (2014). Demand Fluctuation and Supply Chain Integration: Case Studies of Japanese Firms.
[360]Viswanadham, N., & Raghavan, N. S. (1997). Flexibility in manufacturing enterprises. Sadhana-Bangalore-, 22, 135-164.: Kekre, S., & Srinivasan, K. (1990). Broader product line: a necessity to achieve success?. Management science, 36(10), 1216-1232.
[361]Viswanadham, N., & Raghavan, N. S. (1997). Flexibility in manufacturing enterprises. Sadhana-Bangalore-, 22, 135-164. : Feitzinger, E., & Lee, H. L. (1996). Fiscally Responsible Mass Customization. working paper.

level of production in parts held at this point, lower the customization is possible, so if the decoupling point moves upstream more level of customization would be possible, this decoupling point not only impacts the level of customization but the delivery time also. If the decoupling point is near the customer (market), then lower will be the delivery time and delivery cost[362].

Inventories in Model

The above analysis showed that to maintain the inventory level is a crucial decision for the firms, as keeping higher and lower both have its own negative impacts. Moreover, with mass customization, the demand becomes unpredictable and the inventory management becomes much more crucial, firms holding inventories can mitigate input supply shocks or production disruptions, the negative effects of supply chain shock can be curbed with input inventories. Firms can also maintain financial flexibility with inventories. The arguments conclude that inventories are source of risk management and provide flexibility; however, the level of inventories is questionable[363].

In this comparative study, an analysis of three types of inventory stock related to 1) raw material 2) work in progress 3) inventory stock can give an insight into extent of JIT and inventory management related policies. Impact of this variable gives an insight on the OEMs preferences and policies towards inventories. High finished value product will show that company is keeping more goods at high level, raw material inventories will indicate that company is keeping more goods as a raw material at decoupling point, in such scenario inventories are kept at low value while the work in progress will show the activity levels at production point or proportion of in-house operations.

4.2.2.2 Distributional planning

Higher distances in supply chain cause higher logistics costs and more complications[364]. However, as discussed in chapter 3, most of the suppliers of the automakers are located near to them; they are either local suppliers or global suppliers, thus the logistics (between supplier and producer) costs and distribution does not become a major issue, as supplier parks, supplier centres and other such ideas have been evolved. Meanwhile, in the case of automotive industry, another phenomenon is observed, the assembling parts are located in the emerging markets (Asia, South America) but main parts or modules

[362]Blecker, T., & Abdelkafi, N. (2006). Complexity and variety in mass customization systems: analysis and recommendations. Management Decision, 44(7), 908-929.
[363]Bianco, M. (2015). Flexibility and firm value: the role of inventories (Doctoral dissertation, alma). ;Jüttner, U., Peck, H., & Christopher, M. (2003). Supply chain risk management: outlining an agenda for future research. International Journal of Logistics: Research and Applications, 6(4), 197-210.
[364]Aguezzoul, A., &Ladet, P. (2007). A nonlinear multiobjective approach for the supplier selection, integrating transportation policies. Journal of Modelling in Management, 2(2), 157–169.

are developed in the home country and distributed via logistics. In some markets, the whole vehicles are also imported. This phenomenon will be discussed in more detail in this section.

Parts manufacturing in the home country

In In the modern times, when the companies have assembling plants in the emerging markets, the phenomenon has been changed regarding the supply of components. Till 1980s, the suppliers intended to provide the small components putting the responsibility on the assemblers. So manufacturing of seats, exhausts, dashboards, etc. was done in house, however, now many in-house operations are done by the first tier supplier. For example, the European company borsch makes the wide range of standard products which could be used by the wide range of assembler[365]. Despite the start of new assembling parts, companies liked to manufacture many parts in their home country and import it to the assembling plant. For example, Daimler AG Chrysler been assembled in Brazil, but major parts like engine mounting, wheels, tyres, windscreen glass, shock absorbers, relays, trims, electrical components, sensors dashboard, heating/cooling systems, wiring harness etc. were all supplied from Germany[366]. Only fewer parts like plastic parts sets, tail lights, and aluminum wheels were produced locally. This shows that when the car itself was not imported, there were still lots of parts to be imported from the home country. The transfer of major parts in home to the assembling points involves logistics costs and time and complexities away from home.

Since, any car produced is associated with an order. This order can be from the customer or the dealer. In Europe, roughly 50 % of cars orders are specified by the dealers. In the Germany this number is greater than 30 %. Once an order is received a due date is given to the customer, which is normally in the six weeks. Every order is given the date of production, by a Master Scheduling Program (MSP). To assemble this car there is a well-developed system, which estimates the time in between different interval and checks the back log[367]. For the assembling plants in Asia, most of the parts are needed to be imported, in such case; the logistics time for transferring part from Europe to Asia can impact the cost and delivery time.

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[365]Humphrey, J. (2003). Globalization and supply chain networks: the auto industry in Brazil and India. Global Networks, 3(2), 121-141.

[366] https://www.daimler.com/documents/investors/berichte/geschaeftsberichte/daimler/daimler-ir-annual-report-2015.pdf Seen on April 2016

[367]Boysen, N., Emde, S., Hoeck, M., & Kauderer, M. (2015). Part logistics in the automotive industry: Decision problems, literature review and research agenda. European Journal of Operational Research, 242(1), 107-120.

Mass customization and network issues

With the mass customization in operation, where assembling according to customer choice is the main task, it makes much sense to assemble car near markets. With the increasing trend in mass customization, the product variety has massively increased, in such scenario the parts has to be delivered in time to the assembling points, this has become one of the greatest challenge for the automotive industry. The parts to be assembled have to go through all of the steps of general logistics process. Parts logistics is of greater relevance, and in automotive industry it encompasses great challenge[368], however, literature has remained quite in it. There is no study which discusses it with reference to automotive industry.

Example from OEM

BMW AG has 22 plants worldwide. However, the plants outside Europe are only assembling plants. Just like Mercedes-Benz, the production pattern in BMW AG, parts such as engines, brake discs, dashboards, Doors, lids, electric systems, seats etc. are produced in different sites. But it must be noted that all of these sites are in Europe only. The plants outside Europe are only assembling plants such as in Shengyand, Chennai, Thailand etc. Efficient logistics is used to transfer parts from their production sites to the assembling plants. For example, engine and chassis components, plastic components for the vehicle exterior, carbon body components, and electric drive systems, spare and replacement engines and drive shafts are transported from Landshut, Germany to 28 production sites in 13 different countries[369].

Distribution and network analysis in model

To investigate this issue, in our model it will be discussed that to what extent companies are focusing to produce near their markets and how it is impacting the supply chain efficiency under mass customization. Since if the cars are assembled in the far markets, the parts are delivered (modules) to the production sites and making the complexities in the supply chain. The other scenario, which is implied by the automotive companies, is to manufacture car in the home country and deliver it to the markets. The question is which of these two scenarios results in more efficiency under mass customization to answer this; two types of distribution are investigated in the model. Thus, the developed model will investigate that whether it is beneficial to produce near the markets or it is better to produce at home

[368]Boysen, N., Emde, S., Hoeck, M., & Kauderer, M. (2015). Part logistics in the automotive industry: Decision problems, literature review and research agenda. European Journal of Operational Research, 242(1), 107-120.
[369]http://www.bmwgroup-plants.com/en/landshut/technologies.html Seen on May 2017

and transporting the final product. For this purpose, two types of distribution in the supply chain would be estimated, i.e. distribution in sales and distribution in production.

4.2.2.3 **Issues of downstream supply chain**

An important part of the supply chain is downstream supply chain which involves the coordination of flow of goods and information between producers and customers[370]. This interaction between producer and customer is one of the basic foundations for a strong business. However, it is rarely direct, and it further involves lot of processes and elements like delivery process, packing, sales process, dealership, price fairness and experience of negotiations. These several elements impact satisfaction of customer perceived from the sales process, which impact on the customer's satisfaction from the product also. Moreover, efficiency in sales processing also increase the probability that the customer will remain alive (repurchase again). The relation between customer satisfaction and profitability has never been as important as it has gone now, in literature; there is evidence of positive and strong relation between customer satisfaction and profitability[371].Furthermore, it is very important to consider that this link varies not only across industries but also across firms in the same industry. Thus; companies are trending to give importance to customer satisfaction.

Producer-buyer relation under mass customization

Mass customization has made producer-buyer interaction somewhat more important, the main reason behind it is that mass customization is a production technique, in which customer and buyer rely on each other to create the best value, this system demands two way communications (from buyer to producer and from producer to buyer) instead of one way communication (only from producer to buyer). Customer has to go through lot of process before ordering product i.e. picking choices, opting services, filling forms etc. So this process is meant to transfer customer's idea to producer's mind[372]. It is seen that sometime high level of options offered to customer may confuse him instead of increasing his satisfaction; it may also lead to a production of the product which was in actual not desired by the customer[373]. Since large number of quantity may leads to customer confusion, it is thus needed that sales process should be made so much easy and understandable that it doesn't let customer to design

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[370] http://www.ehow.com/info_7753272_downstream-supply-chain-management.html Seen on Oct 2010

[371]Gupta, S., & Zeithaml, V. (2006). Customer metrics and their impact on financial performance. Marketing Science, 25(6), 718-739.

[372]Syam, N. B., & Dellaert, B. G. (2001). Consumer-producer interaction: A strategic analysis of the market for customized products. Review of Marketing Science Journal WP, (424).

[373]Loureiro, S. M., Sardinha, I. M. D., & Reijnders, L. (2012). The effect of corporate social responsibility on consumer satisfaction and perceived value: the case of the automobile industry sector in Portugal. Journal of Cleaner Production, 37, 172-178.

something that is not appropriate or it should not let the customer to get confuse from the variety offered. In the case of automobile industry, application of mass customization has made the producer-buyer interaction more complex, this is due to the reason that automobiles are usually bought through a dealer, customer rarely wants to order the car online so the dealer have to explain customer technically about the options chosen, combinations possible and different packages. While on the other hand, with too many options available customer may get confuse (if not guided properly from the dealer) and the final product received is different from the one in the customer mind. Dealers are main messenger between producer and buyer, so it is very important that they are trained properly to guide customers during the buying process. Another aspect of sales process in the automobile industry is that customizing a car also needs some time as the paint process, delivering process, assembling all are according to customer choice so it requires time which may lead to the decrease in the satisfaction of customer, if the delivery and final steps are taking too long it may have the impact that the customer choice may change. Because of all these factors it is analyzed that mass customization is not as successful in the automobile as in computer and other small products industries[374]. This analysis makes the dealership process more prominent, it is thus important that sales process should be modified according to the needs of customization; it should be made as simpler as possible. So, mass customization puts lot of responsibility on dealer to simplify things.

Delivery processing

Mass production is characterized by shorter lead times, so in order to make mass customization more attractive it becomes important to decrease the delivery time[375]. If the production process is so long or the distance between producer and market is long, it impacts the delivery time and thus delivery processing is affected. These kinds of problems make it difficult to maintain efficiency in the supply chain. If the firm, postpones the production process up to highest level then the lead time will longer thus effecting the delivery processing[376]. After the placement of order, customers are willing to wait for their product; however, they prefer short timings and efficient deliver process. Car manufacturers prefers to reduce the delivery time as much as possible, VW and Ford has managed to do this delivery in

[374]Kahn, B. E. (1998). Dynamic relationships with customers: High-variety strategies. Journal of the Academy of Marketing Science, 26(1), 45-53.
[375]Kahn, B. E. (1998). Dynamic relationships with customers: High-variety strategies. Journal of the Academy of Marketing Science, 26(1), 45-53.
[376]Waller, M. A., Dabholkar, P. A., &Gentry, J. J. (2000). Postponement, product customization, and market-oriented supply chain management. Journal of Business Logistics, 21(2), 133.

up to 14 days while BMW AG has tried to managed it in ten days[377]. These examples clearly demonstrate the race between the automotive companies to reduce the delivery time as much as possible, in this aspect it should be noted that by delivery processing we don't mean the entire supply chain, by fast and efficient delivery system it represents the efficiency in the downstream supply chain, the capability of a manufacturer to produce the customized product on a fast track. The research of UK automotive customer has shown that 61% customers want their car to be delivered in or in less than 14 days[378], in US automotive industry where it is generally perceived that customers like to buy from dealers, 74 % of customers would prefer to order and wait for the car however customers in north Africa will wait not more than three days to wait for their car[379], because of inability to produce within three weeks, many customers preferred to buy from the built to stock products [380]

Dealership facility

In the automotive industry, the producer and buyer relation is distorted by the third party "dealer". Since the relation is not direct, it needs sophistication. Moreover, since it takes time and complexities to produce a car, so in time delivery also becomes a problem. Thus, various such factors e.g. dealers, dealership facility, selling management, delivery time etc., complicates the sales procedure[381]. It is also investigated that different e-services, (which include different online services of ordering, complaining, configuring, etc.) could be used to facilitate customer in mass customization process[382]. However, in the case of automotive customers, it is observed that customer rely more on dealer as compared to these

[377]Blecker, T., &Abdelkafi, N. (2006). Complexity and variety in mass customization systems: analysis and recommendations. Management Decision, 44(7), 908-929.; Holweg, M., & Miemczyk, J. (2002). Logistics in the "three-day car" age: Assessing the responsiveness of vehicle distribution logistics in the UK. International Journal of Physical Distribution & Logistics Management, 32(10), 829-850.

[378]Holweg, M., & Pil, F. K. (2001). Successful build-to-order strategies start with the customer. MIT Sloan Management Review, 43(1), 74 :Elias, S. (2000). New vehicle buyer behaviour-quantifying key stages in the consumer buying process. In 3DayCar annual year end conference, Cardiff.

[379] Christensen, W. J., Germain, R., & Birou, L. (2005). Build-to-order and just-in-time as predictors of applied supply chain knowledge and market performance. Journal of Operations Management, 23(5), 470-481. ; Wire, B. (2001). Gartner survey shows US consumers prefer concept of build-to-order when buying an automobile. Business Wire, 8.

[380] Holweg, M., & Pil, F. K. (2001). ; Successful build-to-order strategies start with the customer. MIT Sloan Management Review, 43(1), 74

[381]Pollard, D., Chuo, S., & Lee, B. (2011). Strategies for mass customization. Journal of Business & Economics Research (JBER), 6(7).

[382]Grenci, R. T., & Watts, C. A. (2007). Maximizing customer value via mass customized e-consumer services. Business Horizons, 50(2), 123-132.

e-services[383]. So customer value achievement under mass customization in automotive industry is of greater concern[384].

Sales management

Under mass customization, sales procedure needs to be much more sophisticated. Unlike conventional sales management under customization, there is interdependence between sales and production[385]. Sales representative needs to tell customer about different options, possible combinations and its outcomes, in other words sales procedure is responsible to translate customer mind to the producer. If it fails then the final product could be totally different from what customer demanded.

Fairness of price

One of the biggest challenge faced by mass customization, is to make prices comparable to mass production system[386]. Although, producer under mass production face less challenges as compared to those faced by the producer under mass customization. However, consumer would not like to pay high differences for customized product. Moreover, with many options there is an increase in price level, e.g. selection of many packages can increase price of car during customization. Thus, it becomes important to determine how much customer is satisfied with these changes in price.

Downstream supply chain issues in model

To measure customer satisfaction regarding the sales process, we follow the approach introduced in the J.D Power studies[387]. There, the authors constructed a number of indicators, which describe different aspects of automotive companies. One of the significant index developed by the study is sales satisfaction index (SSI), which gives a comprehensive analysis of the new-vehicle purchase experience from the customer perspective response with respect to purchase, delivery, sales and price. Further details on the index will be given in the next section.

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[383]Wells, J. D., & Gobeli, D. H. (2003). The 3R framework: improving e-strategy across reach, richness, and range. Business Horizons, 46(2), 5-14.

[384]Pollard, D., Chuo, S., & Lee, B. (2011). Strategies for mass customization. Journal of Business & Economics Research (JBER), 6(7)

[385]Bouwens, J., &Abernethy, M. A. (2000). The consequences of customization on management accounting system design. Accounting, Organizations and Society, 25(3), 221-241.

[386]Alptekinoglu, A., & Corbett, C. J. (2008). Mass customization vs. mass production: Variety and price competition. Manufacturing & Service Operations Management, 10(2), 204-217.

[387]J.D. Power Associates press release (2011), http://businesscenter.jdpower.com/news/pressrelease.aspx?ID=2011199. Seen on Feb 2016

4.2.2.4 **Structure of Model**

The structure of model is developed in Figure 4-2; the impact of three main issues would be discussed in the model. Briefly, the model will incorporate the impact three issues; i.e. inventories policies, distributional policies and downstream supply chain on the supply chain management under mass customization.

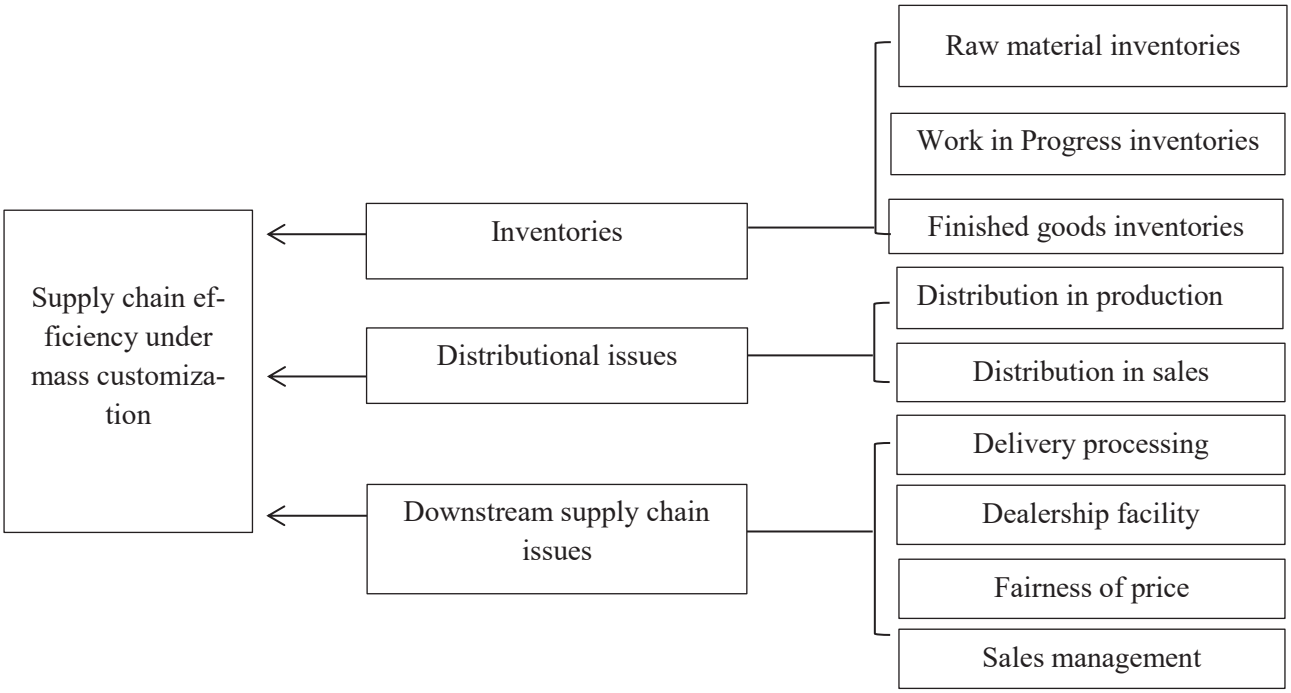

Figure 4-2: Structure of model

4.3 Mathematical construction of the Model Variables

In last section, the issues concerning efficiency of supply chain were discussed, in this section quantitative measures would be described, and the variable will be constructed that would ultimately lead to model development. To find the direct data from the companies is a complex task, however, information on different aspects is released in the annual reports of the companies, moreover broacher; flyers posters etc. are also released. Information from the financial reports of BMW AG, Volkswagen AG and Mercedes-Benz will be used to construct variables related to inventories and distribution, while the yearly broachers of the car models are used to find the customization options. Since the purpose of the model is to see how different variables affects supply chain efficiency under mass customization, so firstly dependent variable will be constructed (in 4.3.2) which will represent supply chain efficiency under mass customization, secondly independent variables will be constructed (4.3.3). The final model

will represent how the different variables (related to inventory policy, distribution policy and down-stream supply chain) are impacting supply chain efficiency under mass customization.
Firstly, in section 4.3.1, we will discuss the time span for which the data is analysed. Then in section 4.3.2 and 4.3.3, dependent and independent variables will be constructed respectively.

4.3.1 Data years

The data from 2007 till 2015 will be used, since the trend of mass customization increased in this time so the data is taken accordingly. The data time has seen the evolution of mass customization trend. Moreover, technology revolutions, business recession (2009-2010) and political change were observed in time. For getting data, Annual reports of the companies from 2007-2015 are used.

4.3.2 Dependent variable

The dependent variable will would show change is supply chain efficiency $\boldsymbol{\Delta Y}$ with the change in mass customization. Firstly, construction of these two variables is discussed; finally a final representation of outcome variable will be derived.

a Profit ($\boldsymbol{\Delta Y}$)

As far as profit is established in a previous section, profit is one of the indicators that could help us to describe the companies supply chain performance, the data of Earnings before Interest and Tax (EBIT) to analyze profit. The reason for using this variable is that it would not encompass the impact of fiscal and monetary indicator and thus can give us clear insight on company's performance. The data on this indicator is available on the yearly financial reports of the companies.

b Mass customization ($\boldsymbol{\Delta MC}$)[388]

"It can be measured by investigating the number of available options. The information on the number of options available is estimated through the broacher of each model. Automotive companies are providing different options to customers for tailoring their products. However, for a customer, the selection of advanced options like driver assistance package and different sports packages is much more difficult than colour selections. So most automotive companies provide

[388] Khan, A., & Haasis, H. D. (2016). Producer–buyer interaction under mass customization: analysis through automotive industry. Logistics Research, 9(1), 17.

yes/no options for advanced packages, while for the upholstery, trim, and exterior colors different choices have to be opted. The measure of the extent of customization (CE), is comprised of the number of options available for trim, paint, packages, upholstery, wheels, etc.

$$MC = \prod_{i=1}^{7} x_i \quad (1)$$

Where $x1$=No. of options for paint, $x2$=No of options for upholstery, $x3$=No of options for trim, $x4$=No of options for wheel, $x5$=No of individual options available, $x6$=No of additional packages, $x7$=No of Steering wheel options.

For all three companies, customers are allowed to customize the car through phenomena known as "Build your own car". CE is evaluated for different models of each company, i.e. for Mercedes-Benz the evaluated models are E class, C class, S class, Cls class, and G class, for Volkswagen AG Model Passet, Jatta, CC and EOS are used, while for BMW AG series 7, 6, 3 and 1 are used. It is found that for each company in each year, customization options are almost same for all models. However, to get more valid results, we evaluated CE for every model separately and took the averages to get the final values". The estimated values of MC for all three companies are shown in the table 1 in the appendix.

c Dependent variable representation

After getting data on supply chain efficiency and mass customization, we now derive the dependent variable.To see how supply chain efficiency has been impacted with changing mass customization we would use the term, $\boldsymbol{Y}$, which is our dependent variable and would show change in supply chain efficiency with the changes in mass customization, equation 2 thus defines our dependent variable as

$$Y = \frac{\textbf{Change in supply change efficiency (Profit)}}{\textbf{Change in Mass customization}} = \frac{\Delta Y}{\Delta MC} \quad (2)$$

4.3.3 Independent variables

4.3.3.1 **Inventories**

Data on Inventory stock is available in each yearly financial report for the time span described in 4.3.1, (2007-2015). The inventory data would be used from three stages of production, raw material, work in progress and finished goods inventories. All three levels will give information about different stages of production. The data on raw inventory stock gives insight to the extent of JIT, the data on work in progress will give details on in-house operations, while finished goods data would give insight on lead

time. The data is taken as a change from the previous year, thus it would generate not only stationary series but will also show the policy changes which are not related to output produced that year.

ΔIR = Inventory of raw material (2)

ΔIW =Inventory of work in progress (3)

ΔIF=Inventory of finished products (4)

The relation in the model would be like following:

$$Y = f(\Delta IR) \quad (5)$$

$$Y = f(\Delta IW) \quad (6)$$

$$Y = f(\Delta IF) \quad (7)$$

Therefore, equation 6, 7 and 8 will show the impact of change in inventories level on supply chain efficiency under mass customization.

4.3.3.2 **Network Distribution**

As discussed in section, 4.1.2.2, that automotive companies have assembling parts in different parts of the world, while the modules like engine, axels etc. are delivered from the home country (Germany in selected cases). Moreover, since the production in the assembling plants in far countries plants is not always enough to meet the local demand, so there is also high number of cars being imported. The purpose of this variable is to capture both of these impacts.

Companies can be either more centralized, which will mean they will produce a bulk in home and spread it to different markets in the world while the other way is more global, which means to produce near the markets, thus reducing the logistics costs and understanding the local market much better. In the former case, the delivery time will be much larger, transportation costs will be higher and flexibility will be lower, this will be vice versa in the latter case. These two factors would be focused while analyzing distribution in the network. Moreover, to measure the impact of network in the supply chain, two terms distributional division in production and sales will be introduced. This will check that either company like to produce more in home or near the markets. Description for the calculation of these two terms is given below:

- **Distribution Division in Production (DdP)**

  It will be calculated for the distance that the parts have to travel to reach the production point. If the company is producing more near the markets, it has to transport more parts to the assembling sites. Thus in this case DdP will rise. For the calculation of parts, we are observing that for how much

cars the parts have been transported. E.g. If 100 Mercedes-Benz is assembled in Brazil, than it means that modules (parts) for 100 cars have travelled to Brazil from Europe. However, in the case of Volkswagen AG, it was found that they produce almost 50% of parts near the production sites, instead of producing that in home[389], it is taken into account while calculating DdP.

The higher the volumes those companies produce away from home; near the markets higher will be DdP. Moreover higher the distance from the home, higher will be DdP.

- **Distribution Division in sales(DdS)**

It will be calculated for the distance that the final products (volumes) have to travel to reach the final destination to meet customer. If, the companies are producing more in home and delivering the final product then this variable will be larger. If the company starts production in any country 1, the imports of vehicles will be declined, as the local production through assembling plant will impact the imports.

After describing the nature of these two variables, now we will discuss the method of calculating these variables. The terms Distribution distance (Dd) in DdP and DdS will measure the proportional amount of logistics that would be used, i.e. it measures the spread & concentration of supply chain to different regions. This variable will be constructed to see how much transportation company have to undergo. This variable will be affected by two relations; firstly if the distance (D) will increase then the distribution distance (Dd) will increase, Secondly, if the amount of product (d) to be transported increases then also distribution distance Dd will increase.

$$Dd \propto D \tag{8}$$

$$Dd \propto d \tag{9}$$

For example, if production is taking place in Germany and product is transported to America, then the spread Dd is less if only 1 % products are transported but however if the amount of product to be transported increase then this distributional distance Dd will increase. Moreover, if the distance increases than Dd will also increase so if the amount of product is kept constant then Dd of any country in Europe (from Germany) will be lesser as compared to Dd for America (as distance of European country from Germany would be lesser). So, Dd will be positively affected by the distance & amount of product to be transported to the country. In other words we can say that Dd will actually measure the logistics used by the company. If the quantity to be transported increase Dd increase, while if the distance through which the quantity has to travel increase than the Dd will increase. For any specific

[389] Volkswagen 2014 http://annualreport2014.volkswagenag.com/ Seen on May 2016

company, it is positively affected by the distance and amount of product to be transported to that location. For any country 1, DdP and DdS would be calculated as follows:

DdP_1= Proportional product (parts) transported * proportional distance from home country (10)

DdS_1= Proportional product (vehicles) transported * proportional distance from home country (12)

Equation 11 and 12 shows that how DdP and DdS would be calculated for one country, the total or final DdP and DdS would be calculated by aggregating the DdP and DdS for all the countries in the distribution list. The information of variables (about products transported) is available in the financial reports of the companies.

$$DdP = DdP_1 + DdP_2 + DdP_3 \ldots \quad (11)$$

$$DdS = DdS_1 + DdS_2 + DdS_3 \ldots \quad (12)$$

$$\Upsilon = f(DdP) \quad (15)$$

$$\Upsilon = f(DdS) \quad (16)$$

4.3.3.3 **Issues of downstream supply chain**

To measure customer satisfaction regarding the sales process, the approach introduced in the J.D Power studies is used.[390] This study has constructed number of indicators, which describe different aspects of automotive companies. One of the significant indexes developed by the study is Sales satisfaction index (SSI), which gives a comprehensive analysis of the new-vehicle purchase experience from the customer perspective response with respect to purchase, delivery, sales and price. We employ the SSI index to measure for satisfaction given two different categories: buyers (who ultimately buy the product) and rejecters (who due to some of the reason leave the product). In accordance with the J.D. power studies, we utilized a weight of 51 % for buyers and 49% for rejecters to compute SSI for US automotive customers via the formula shown in Eq. 2. Since, SSI is constructed by using a large amount of data, it allows to generate a meaningful picture of customer satisfaction regarding the sales process.

Buyers Rejecter

SSI=f(Working of deal, Delivery process, Dealership facility, sales person, Price Fairness, Facility, Inventory, Experience Negotiations)

$$\boldsymbol{\Upsilon = f(SSI)} \quad \textbf{17}$$

The weights for subcategories proposed in J.D. power studies are given in Table 8 shown in appendix. We like to note that all variables shown in Table are impacted by mass customization. Since mass customization adds a lot of complexity to the buying process, it demands modern dealership facilities,

[390]http://businesscenter.jdpower.com/news/pressrelease.aspx?ID=2011199. Seen on Feb 2016

informed sales persons and efficient dealing. Similarly, delivery time is important in the case of mass customization because cars are mainly assembled after the placement of the customer's order.

4.3.4 Final Representation of Model

Combining equation, 2, 6,7,8,15,16 and 17 would result in a model

$$Y = f(\Delta IR, \Delta IF, \Delta IW, \Delta SSI, \Delta DdP, \Delta DdS) \quad (13)$$

Where Y would show change in supply change efficiency with the change in mass customization. Thus the model will show proportional change in profit under mass customization due to the independent variables, which represent different aspects of the supply chain. Theoretically, the equation will answer how changes in the network spread, inventories, and sales satisfaction is impacting supply change efficiency with respect to mass customization.

4.4 Data analysis for the Model variables

After variables construction, we are able to get the data on all of the variables. In this section we will analyze the data developed. This will not have an impact on the results from the econometric analysis, but it will give us insight into the companies' policies.

4.4.1 Data on Inventories

The data all types of inventories is taken from the annual reports of Mercedes-Benz, BMW AG and Volkswagen AG. This variable will determine the extent of JIT applied in each company, since the amount applied depend upon the quantity been produced, thus we would only determine the trend in the variable.

4.4.1.1 **Raw material Inventories**

The data on raw material inventories is shown in table 3 in appendix. Figure 4-3 shows raw material inventories at Mercedes-Benz, the trend shows that although inventories are increasing with time, but that is not with any major transition. Thus company showed more or less consistent policy regarding JIT from 2007 till 2015.

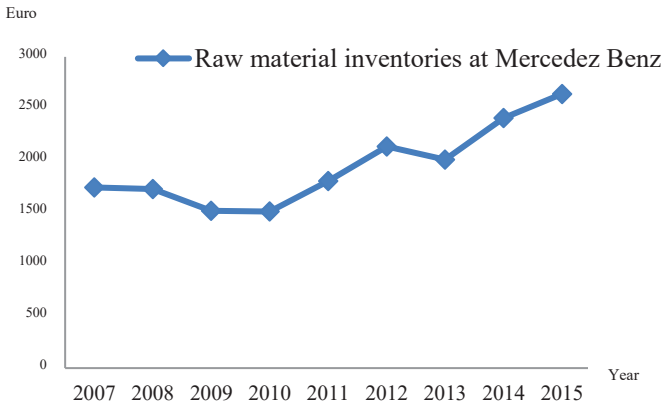

Figure 4-3: Raw material inventories at Mercedes-Benz

Raw material inventories policy at BMW AG is more or less same at Mercedes-Benz with no sharp decline or rise. It increases with time, due to increase in level of production. The trend of inventories at BMW AG is shown in Figure 4-4.

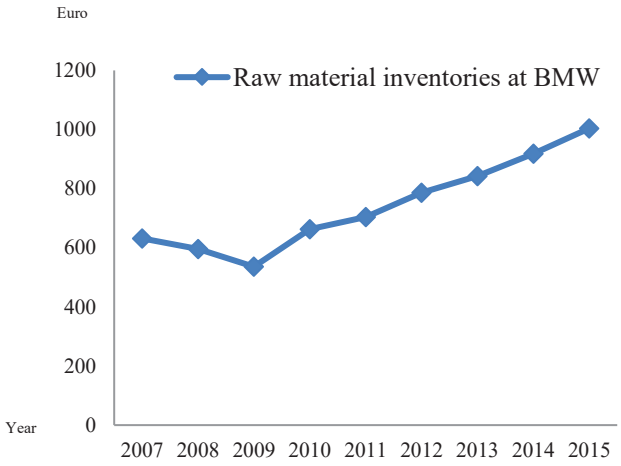

Figure 4-4: Raw material inventories at BMW AG

The inventories at Volkswagen AG shows a different trend then of Mercedes-Benz and Volkswagen AG, as discussed in previous chapter the company changes its policy regarding in-house operations and moved towards outsourcing, the changing level of inventories pattern reflex this. After 2013 the raw material inventories shows a decline, which is due to preference of outsourcing. The trend in Raw material inventories of Volkswagen AG is shown in Figure 4-5.

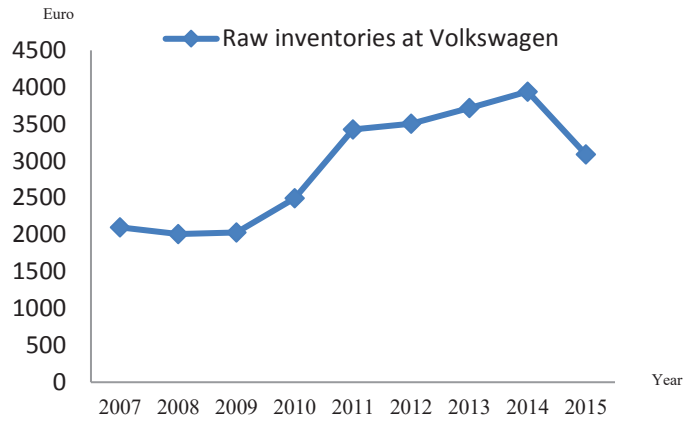

Figure 4-5: Raw material inventories at Volkswagen AG

Thus the data of raw material inventories at Mercedes-Benz and BMW AG almost followed the same pattern; however, the data at Volkswagen AG is showing changes in policy preferences.

4.4.1.2 Data on Work in progress inventories

The data on work in progress inventories will show the preference for in-house operations or outsourcing, this data is shown in table 4 of appendix. Figure 4-6 show the level of work in progress inventories at Mercedes-Benz. As shown, the preference for work in progress inventories is not consistent like raw material inventories. Company preferred to increase work in progress inventories in 2011 but declined in 2013. However, it increased again after 2015.

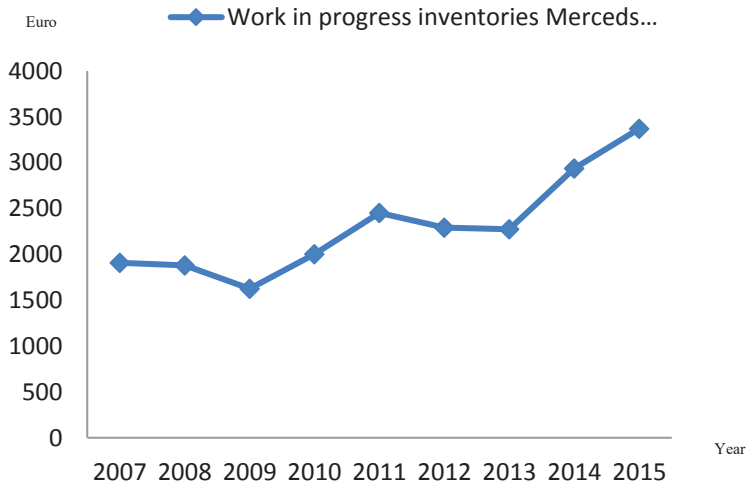

Figure 4-6: work in progress inventories at Mercedes-Benz

Work in progress inventories at BMW AG as shown in Figure 4-7, shows a sharp decline in 2009 which represents company's suffering from global financial crisis. However, there is a declining trend after the regain of 2011 which shows the preference for outsourcing as in-house operations were declining.

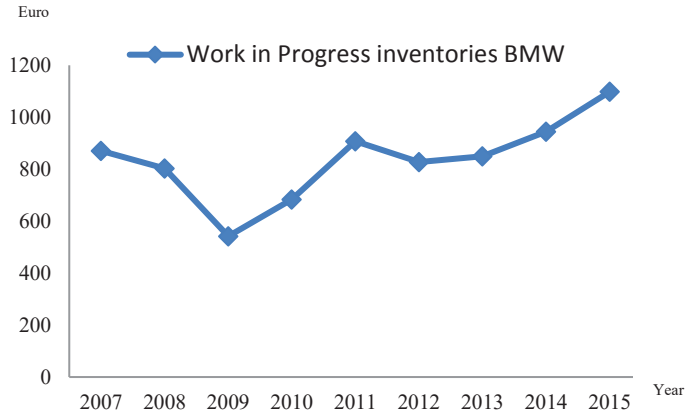

Figure 4-7 work in progress inventories at BMW AG

Figure 4-8 shows work in progress inventories at Volkswagen AG. There is high rise of work in progress inventories after 2010. However, it declined a bit in 2013 which shows company's minimal trend towards outsourcing but as analysis from chapter 3 shows that Volkswagen AG prefers in-house operations more than BMW AG and Mercedes-Benz.

Figure 4-8: Work in progress Inventories at Volkswagen AG

4.4.1.3 Finished goods inventories

The level of finished goods inventories under mass customization should be lower as inventories are kept on their highest value when they are in the form of finished goods inventories. With the mass customization, the focus should be to decrease inventories of finished goods, as it would indicate the

delivery time is lower. The data on finished goods inventories is shown in Table 5 in appendix. However, the rise in finished goods inventories with time also indicates the higher production at company. Figure 4-9 shows the level of inventories at Mercedes-Benz, there are no major disruptions, and the trend is quite consistent for 8 long years.

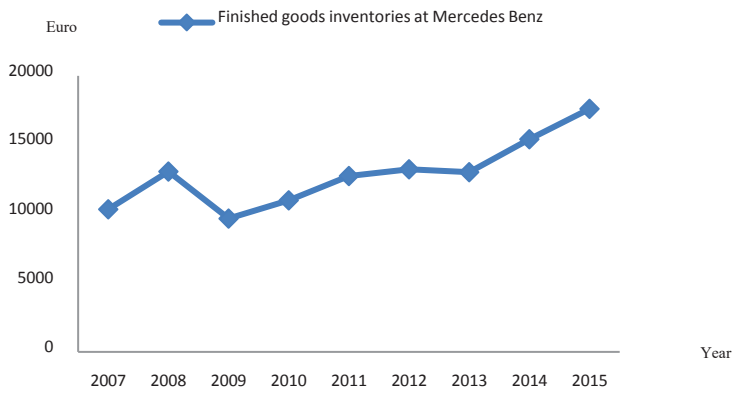

Figure 4-9: Finished goods inventories at Mercedes-Benz

The level of finished goods inventories at BMW AG also shows the same trend as Mercedes-Benz, it is consistent slightly rising trend as shown in Figure 4-10, the trend is much similar to Mercedes-Benz.

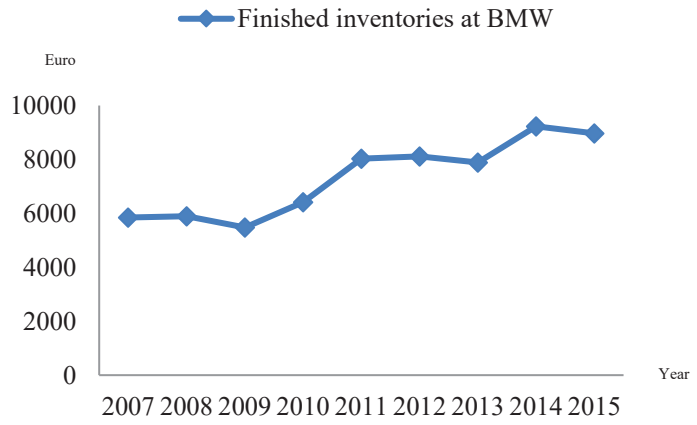

Figure 4-10: Finished goods inventories at BMW AG

The level of finished goods inventories at Volkswagen AG is shown in Figure 4-11, it is not consistent, it can be seen that Volkswagen AG was pretty much affected by the global recession of 2008, as all three types of inventories have declined sharply in the recession period.

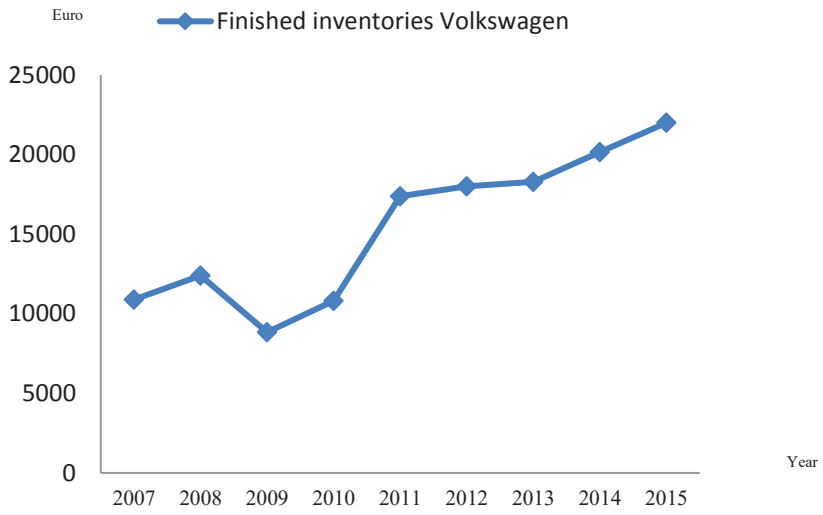

Figure 4-11: Finished goods inventories at Volkswagen AG

4.4.2 Distribution issues

4.4.2.1 Distribution in production

As discussed in last sections, distribution in production will indicate that how much modules company has to transfer to the assembling plants, from the home country to the assembling country. It is observed that there would be sharp rise in this variable, as a new plant opening would impact the DDP drastically. The variable is constructed for all three companies.

The data on DdP for all three companies is shown in Table VI in appendix. Firstly we observe DdP at Mercedes-Benz in Figure 4-12, it is seen that the DdP rose drastically in 2011, when the plant in Asia was being built.

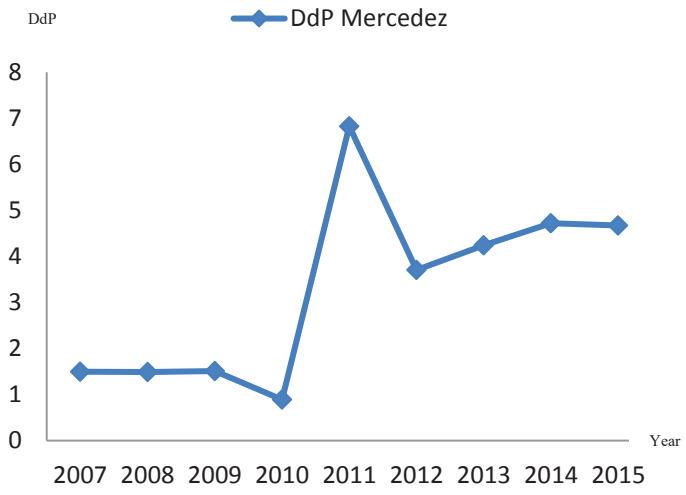

Figure 4-12: DdP at Mercedes-Benz

Since BMW AG, also developed plants in Asia (India and China), thus DdP at BMW AG also show a steady rise after 2010[391], the rise is much consistent, unlike Mercedes-Benz. However, after 2014, there is no further rise observed, Figure 4-13 shows this trend of Mercedes-Benz.

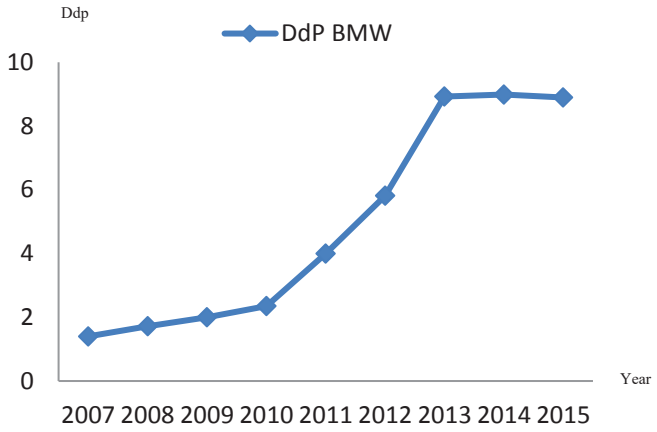

Figure 4-13: DdP at BMW AG

Since the operations of Volkswagen AG are much more global, even before 2010, thus we do not observe sharp rise of DdP at Volkswagen AG, unlike BMW AG and Mercedes-Benz. As shown in Figure 4-14, there is steady minimal rising in DdP after 2007, which indicates that the already existing operations in global plants rose.

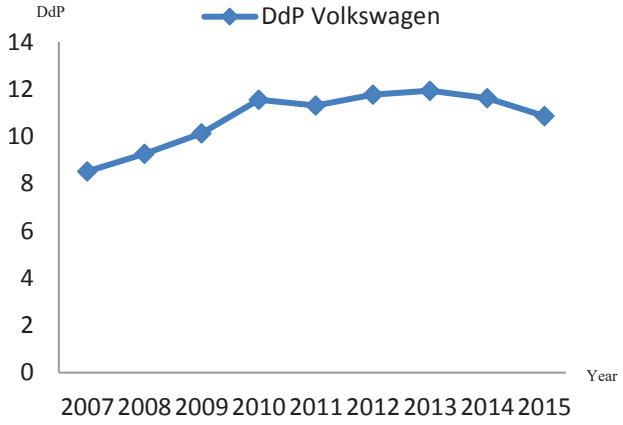

Figure 4-14: DdP at Volkswagen AG

[391] BMW financial report 2011.
http://annual-report2011.bmwgroup.com/bmwgroup/annual/2011/gb/English/pdf/report2011.pdf
Seen on May 2017

4.4.2.2 **Distribution in sales**

As discussed in last sections, DdS will indicate that how much automotive company is importing the final product to the markets. Theoretically with the rise in DdP, DdS would rise, since when the production started near the market the less final auto motives would be transferred to that market. The data in Dds for all three companies is shown in table 7 in appendix. Figure 4-15 shows the DdS at Mercedes-Benz , as it can be observed from the figure, DdS has shown ups and down, which indicated in consistent demand in the markets

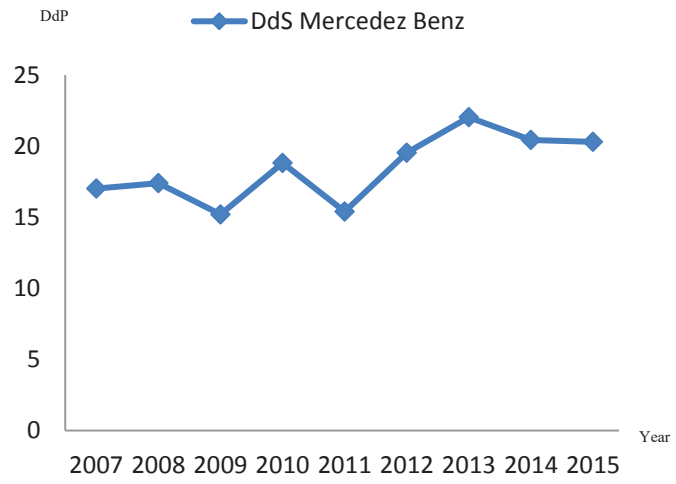

Figure 4-15: DdS at Mercedes-Benz

DdS at BMW AG, shows a decline after 2011, this is due to the reason that after 2011, the plants were built in the markets, thus DdP rose. Therefore, there was less need to import a complete vehicle to those markets, (because of local production) thus DDS declined. Figure 4-16 shows this trend more clearly.

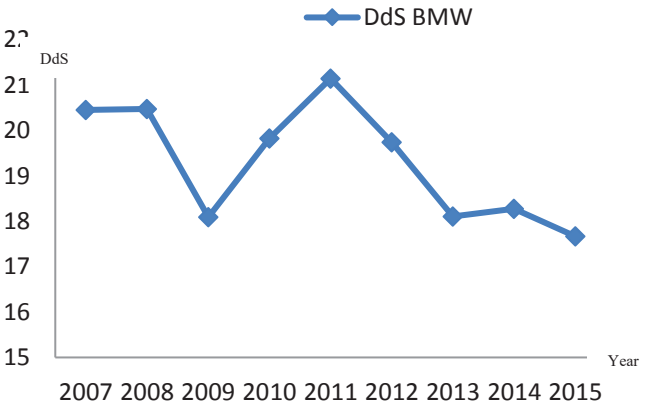

Figure 4-16: DdS at BMW AG

DdS at Volkswagen AG shows a consistent rise after 2010, completely opposite to BMW AG, showing that Volkswagen AG was transporting more vehicles to markets than before. At this time, DdP does not shows any changing, which means that Volkswagen AG preferred to meet the higher demand through the plants in the home country, the trend of DdS at Volkswagen AG in shown in Figure 4-17.

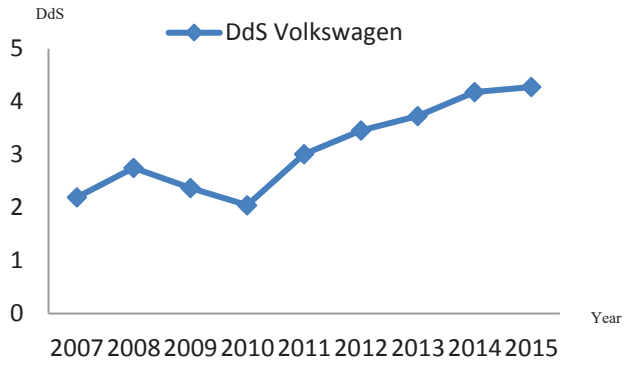

Figure 4-17: DdS at Volkswagen AG

4.4.3 Downstream supply chain issues

As discussed, in last section SSI indicates the problems in the downstream supply chain. How well the company is managing its downstream supply chain is indicated through this variable. The data all three companies, about this variable is observed in this section. The various criteria used in the development of this index are shown in table 8 in the appendix. While the data of all the companies for this variable is shown in table 2 in the appendix. As shown in Figure 4-18, SSI at Mercedes-Benz showed at decline after 2011. This was the time when company also suffered from crisis due to the merger. After this decline, we don't observe any betterment in the trend.

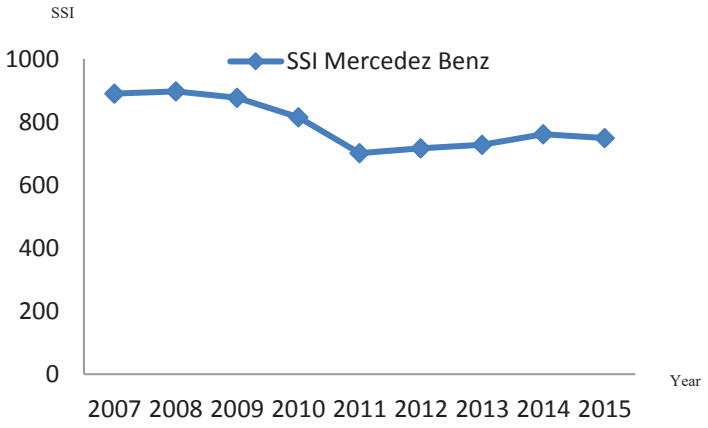

Figure 4-18: SSI at Mercedes-Benz

Just like Mercedes-Benz, SSI at BMW AG also showed the same trend after keeping high position till 2011, the variable declined in 2011. However, there was slight betterment after 2012, as shown in Figure 4-19.

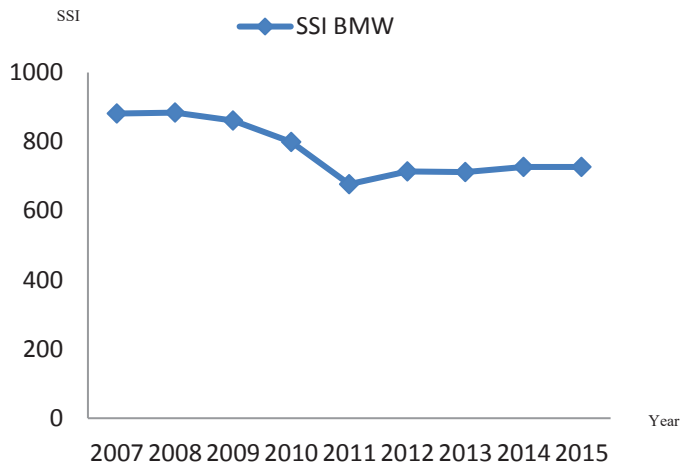

Figure 4-19: SSI at BMW AG

The trend of SSI at Volkswagen AG is shown in Figure 4-20, just like BMW AG and Mercedes-Benz, SSI at Volkswagen AG also declined after 2010, this was the time when mass customization in automotive industry was increasing. Thus with the rise in mass customization, the issues in the downstream supply chain increased, which resulted in the lower customer satisfaction from the downstream supply chain.

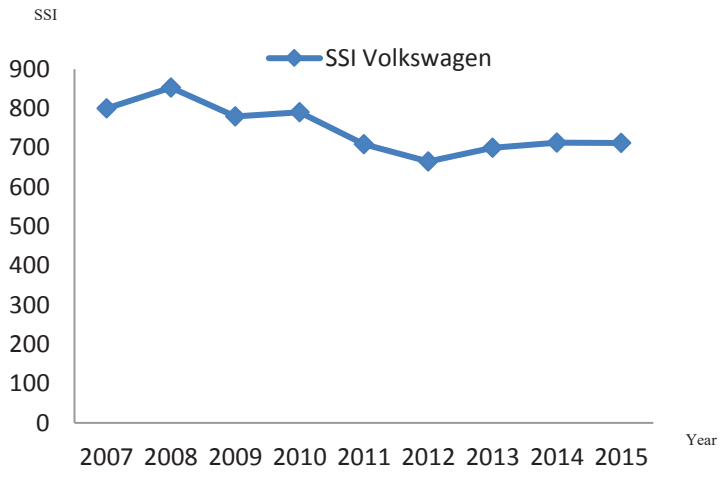

Figure 4-20: SSI at Volkswagen AG

In the analysis of the data above, different trends in the automotive policy regarding distribution, inventories and downstream supply chain issues, were analyzed. Although this analysis has not linkage

with the model development and estimation in the next section, but it revealed the preferences of companies regarding different issues.

4.5 Model estimation by Panel Analysis

4.5.1 Panel estimation

Panel data can be estimated by the Fixed and Random effect. The main difference between two is that in the fixed effect model the constant is treated as a group (section) specific. An alternative method for estimation is random effect model, which handles constants of each variable not as fixed but as a random parameter[392].

To choose between Fixed and random effect, there is need to investigate that whether the regressors are correlated with the individual effect. The benefit of fixed effect estimator is that it is consistent even when the estimators are correlated with the individual effect. Usually, when the panel data is balanced, fixed effect gives more appropriate results as compared to the random. Moreover Hausman test can be used to investigate further that whether fixed or random effect should be used. But it should be noted that this test would investigate that when the fixed effect model is appropriate, would the random effect estimation would be as appropriate[393]. The above discussion, (balanced data panel and Haussmann test) suggest us that fixed effect model would be appropriate for our panel analysis. As we have balanced analysis and the number of regressors suggest selecting fixed effect model.

4.5.2 Fixed effect estimate

The fixed effect estimates are also known as least square dummy variables because in order to allow for different constants for each group it includes a dummy variable for each group. A simple panel data matrix representation for fixed effect is shown below. Consider a panel data analysis, with N number of cross sections, observed for different time periods T, a simple linear model is formulated with only one explanatory variable.

$$Y_{it} = \alpha_i + \beta 1 X1_{it} + \beta 2 X2_{it} + \cdots + \beta k X k_{it} + u_{it} \quad (19)$$

Here variable have subscripts i and t, i =1, 2……N sections and t=1, 2….T time periods. Including dummy for least square dummy variable (LSDV) it can be represented as follows:

[392] Asteriou, D., & Hall, S. G. (2015). Applied econometrics. Palgrave Macmillan.
[393] Asteriou, D., & Hall, S. G. (2015). Applied econometrics. Palgrave Macmillan.

$$Y=D\alpha+X\beta+u \quad (20)$$

$$Y=\begin{pmatrix} y1 \\ y2 \\ \vdots \\ yn \end{pmatrix}, \qquad D=\begin{pmatrix} it & 0 & 0 \\ 0 & iT & 0 \\ \vdots & \vdots & \vdots \end{pmatrix} \qquad X=\begin{matrix} it & 0 & 0 \\ 0 & iT & 0 \\ \vdots & \vdots & \vdots \end{matrix},$$

$$D=\begin{pmatrix} it & 0 & 0 \\ 0 & iT & 0 \\ \vdots & \vdots & \vdots \end{pmatrix} \qquad X=\begin{matrix} it & 0 & 0 \\ 0 & iT & 0 \\ \vdots & \vdots & \vdots \end{matrix} \qquad \alpha=\begin{pmatrix} \alpha 1 \\ \alpha 2 \\ \vdots \\ \alpha n \end{pmatrix} \beta=\begin{pmatrix} \beta 1 \\ \beta 2 \\ \vdots \\ \beta n \end{pmatrix}$$

Here dummy variable allow us to take different group specific estimates for each of the constant for every section.

4.5.3 Panel Implementation

In In this study three companies are being analyzed from 2007 till 2015. So there are three cross sections with 8 years of time span. Since the mass customization, is a recent phenomenon it is not possible to get data for a much larger time span. Time series data analysis requires the data availability of minimum 25 observations, which is not possible for year's data. On the other hand cross section analysis does not provide us with the option to see changes with the passage of time. The best option for this case is to move towards the panel data analysis

4.5.4 Structural Form

The above mentioned arguments lead us to the conclusion that panel data is best suited for the study, it is already discussed what is panel data, what are its forms, why this analysis is selected. The data can now be arranged in the tabular form to make the analysis easy for understanding and to carry out further statistical techniques. Table IX shows the data arranged as a panel in appendix.

4.5.5 Stationarity in the data

In principle, regression based on non-stationary panel variables may prove spurious as in the case of time-series. However estimates of the structural parameter binding two independent non-stationary variables converges to zero, as in the case of panel data, whereas in the case of time series it is a random variable[394]. This means that although non-stationary panel data may lead to biased standard errors, the point estimations of the value of parameters are consistent. To avoid the problems, and to get more

[394] Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. Journal of econometrics, 90(1), 1-44

precise results, it is recommended that if some of the series in the model are not stationary at the level, then it is better to consider either error correction model or to consider panel at first difference.

Our data is already taken in differences, as it was more appropriate theoretically. This helped to overcome lot of statistical problems of stationarity and normal distribution. However using the data, at difference has actually decreased the number of observations, but since the data will be with less statistical problems so results will be more accurate. Model would show how the changes in the dependent variables are explained by the changes in the independent variables. This model will show proportional change in profit under mass customization due to the independent variable, which represents different aspects of the supply chain.

4.5.6 Pooled least square

The model was tested with fixed effect, the result of pooled least square are shown in this section.

4.5.6.1 **Individual statistics results**

$$Y\_1 = 1.01 + PER\_EFFECT - 8.68 + 0.01*LR\_1 + 0.27*LSSI\_1 + 12.48*LDP\_1 + 8.21*LDS\_1 + 0.01*IF\_1 - 0.017*LW\_1 \quad (21)$$

$$Y\_2 = -6.57 + PER\_EFFECT - 8.68 + 0.01*LR\_2 + 0.27*LSSI\_2 + 12.48*LDP\_2 + 8.22*LDS\_2 + 0.01*IF\_2 - 0.017*LW\_2 \quad (22)$$

$$Y\_3 = 5.56 + PER\_EFFECT - 8.68 + 0.01*LR\_3 + 0.27*LSSI\_3 + 12.48*LDP\_3 + 8.21*LDS\_3 + 0.01*IF\_3 - 0.01*LW\_3 \quad (23)$$

Here the representation of these variables is as follows:

$$\Delta IR = LR \quad (24)$$

$$\Delta IF = LF \quad (25)$$

$$\Delta IW = LW \quad (26)$$

$$\Delta DDP = LDP \quad (28)$$

$$\Delta DDS = LDS \quad (29)$$

$$\Delta SSI = LSSI \quad (27)$$

4.5.7 Model results

The results from the panel data analysis are quite significant. Four out of six variables are significant below 8% level of significance while remaining one is significant at 15% level of significance. Thus most of the variables in the model are showing significant impact. In other words the selected parameters, inventories change, network spread change and sales satisfaction change has significant role in causing proportional change in profit under mass customization change. The results achieved using

econometrics software Eviews 8. The results achieved are shown in Table 4-1, the details are discussed in next section. The final data form of the model is shown in Table IX in the appendix.

Dependent Variable: ***Y***
Method: Pooled Least Squares
Date: 06/01/16 Time: 16:21
Sample: 2008 2015

Independent Variable	Coefficient	Std. Error	t-Statistic	Probability
C	-8.68	4.66	-1.862017	0.09
LR	0.01	0.01	1.440954	0.18
LSSI	0.27	0.10	2.578454	0.03
LDP	12.48	4.06	3.072499	0.01
LDS	8.21	3.48	2.360808	0.04
IF	0.05	0.01	1.932994	0.08
LW	-0.01	0.01	-1.576659	0.15

R-squared	0.82	Mean dependent var	-0.706407
R-Adjusted squared	0.50	S.D. dependentvar	13.63890
F-statistic	2.54	Durbin-Watson stat	1.615893
Prob(F-statistic)	0.092	S.E regression	9.62

Table 4-1: Estimation results from panel data analysis
Source: Author's Calculation

4.5.8 Results discussion

4.5.8.1 **Inventories**

The impact of inventories on profit under mass customization is higher as expected and as suggested by literature. Finished goods inventories are contributing less and less significant impact on profit; this is due to high cost of these inventories at highest value point[395]. Raw material inventories are contributing much positive to the profit; it is because of the fact that if higher raw materials are placed at the

[395] Blecker, T., & Abdelkafi, N. (2006). Complexity and variety in mass customization systems: analysis and recommendations. Management Decision, 44(7), 908-929.

decoupling point, it results in efficient production, early deliveries, easy distribution and lesser cost (as the inventories are not kept at the highest value). It is investigated that keeping other variables constant, about 1 unit rise in raw material inventories will result in the .017 unit rise of profit under mass customization. This relation is however slightly insignificant on the contrary the impact of finished goods inventories on the positive is quite minute, 1 unit rise in the finished goods inventories leads to the rise of profit (effected by mass customization) by only by .004 unit, when other variables are kept constant and its significant at 10% level of significance. Since the cost of inventories at finished product level is quite low, so its contribution to profit is quite low. The positive impact is however due to the reason, that many people go to the dealers and prefer to buy the care are made and established there. The surprising factor from the results is that work in progress is impacting negatively to the profits, this indicates that manufacturing at OEMS should be reduced, this is well proofed by the literature which shows that average production at OEMs under mass customization is declining, contributing to simplify the production at plants, our results supports this theory, higher the production level at OEMs it would contribute negatively to the profits[396]. So under mass customization, production depth at assembling lines should be declined. The results shows that, keeping other variables constant, a 1 unit rise in work in progress inventories declines the profit under mass customization by .017 unit. These results are significant at 15% level of significance. So all the results for inventories are supporting views from literature and theoretical analysis from chapter 3, inventories for work in progress should be minimized, and the parts to be assembled can be increased up to the decoupling point, which makes the supply chain more flexible.

4.5.8.2 **Distributional distance**

The purpose of this variable was to investigate that whether it is more efficient to produce near the markets or its more efficient to produce near the home (from where the parent company belongs and produce majority of the parts, which travel to get assemble). Since both of the assigned variables are calculated with the point of view of production, so they both contribute positive to the supply chain efficiency. However DdP contribute more as compared to DdS. Keeping other things constant, about 1 unit rise in DdP contribute 12 unit in profit (under influence of mass customization) while 1 unit rise in DdS increase profit by 8 unit, under mass customization. Both of these variables are significant at 5 % level of significance. The results indicates that it is more profitable to produce near the markets, this is because of the fact that it causes lesser delivery time, more flexibility , lesser delivery cost (cost of transferring the whole car is much higher than the cost to deliver the parts of that car). Although

[396] Krcal, H.-C. (2007). Strategische Implikationen einer geringen Fertigungstiefe für die Automobilindustrie. Discussion Paper Series No. 456, University of Heidelberg, Germany.

producing near home, enables firm to control many circumstances, however the producer cannot understand the market demand so clearly by sitting far. Especially for the Asian customers, where the market is much different from the European market, sitting in the market help the producer to compete the local producers also. Due to all of these factors, the results from the analysis supported the fact that production near the markets is more favorable to the firm. Producing in home and transferring to the markets also have positive impact, but this is not as strong impact as that producing near the markets.

4.5.8.3 **SSI**

The last variable in our equation investigate the impact of various factors attributed in the downstream supply chain. This variable covers the impact of dealership facility, price fairness, inventory management at dealer, delivery processing, and various such factors. As expected, this variable is impacting positively on profit under mass customization. The important feature deducted from the results is the significance of this impact. Keeping other things constant, about 1 unit rise in the SSI results in the rise of profit by .28 units, the results are significant at 5 % level of significance. The results indicates the high importance of this variables, in a typical supply chain relation with suppliers, management of inventory, distribution in the network are important, but the downstream supply chain elements are equally important for profit. If the customer is disappointed at the dealership facility, or a dealer from an online service or from the delivery time, then the probability that he will reject the product increases. This variable glorifies the importance of downstream element in the supply chain.

4.5.9 Results validation

In this section we would discuss different test, which would be used to validate the results.

4.5.9.1 **R square**

R square measures that how much variation in the dependent variables is measured by the explained independent variables, it actually measures that how close the data is to the fitted regression line, it is also knows as the coefficient of determination. The simple and straight forwards definition is that it "it is the percentage of the response variable variation that is explained by a linear model"

$$\text{R-squared} = \text{Explained variation} / \text{Total variation} \quad (28)$$

R square ranges from 0 to 100 %, 0 % indicate that no variation is explained by the variables in the total variation, while 100 % means that all the variation in the model is explained.

R-squared is always between 0 and 100%, 0 indicates that there is no variation in the model explained by the independent variable. However when the r square gets too high, it is associated with the statistical problems. It means that model is over interpreted. In analysis focus should not be to attain high r

square, focus should be to attain significant, it is possible that we obtain a model that is not significant but r square is above .80 while on other side sometime r square as .3 could be with significance. R square has a very modest role in the model, not the high R square shows the goodness of model nor does the low R square show that the model is weak. In our example, R square is .82 which shows that about 82 % variation in the dependent variable is explained by the independent variables[397].

4.5.9.2 **Adjusted R square**

Since R square, is usually over interpreted, so to adjust it, adjusted R square is used, there are several benefits of using adjusted R square over the R square. By simply adding the variables in the model R square rises, so it is inaccurate measure to predict goodness of fit. Adjusted R square is only increased when the t value of the variables in the model is significant. Adjusted r square is lesser than R square. In a data which include different cross sections, R square is low, one should not worry about it as the main task is to achieve the regressors with the correct coefficient[398]. The main difference between adjusted R square and R square can be understood by observing the following points:

1. Adjusted R square considers the number of independent variable in the model whereas R square does not.
2. If we add more variables in the model. The adjusted R square will only increase if the t value of the coefficient is greater than 1 (showing significance)
3. Adjusted R square is not biased

4.5.9.3 **F test**

R square gives idea about the relation between Explained variables and the dependent variable. However, R square is not zero, even when there is no relation between dependent and the independent variable. In this situation the question arises, that how and when we can trust R square.

To check the significance of R square F test was developed by Ronald Fischer, 1890 to 1962. F distribution is bounded below zero; it has its own frequency distribution.

F is calculated as

$$F = \frac{R^2}{k-1} / \frac{1-R^2}{n-k} \quad (29)$$

- Where n is number of observations
- ***k*** is number of parameters

[397] Gujarati, D. (2004). Basic Econometrics. United States Military Academy, West Point.

[398] Gujarati, D. (2004). Basic Econometrics. United States Military Academy, West Point.

After calculating f statistics from the above mentioned formula, it is tested against the F value from the chart. If $F_{calculated}$ is greater than $F_{critical}$, then it shows to reject the null hypothesis, the null hypothesis in our case is

Null Hypothesis: The independent variable does not show any variation in the dependent variable.

Alternative hypotheses: The independent variable shows variation in the dependent variable.

$$F_{cal.} > F^{(k-1,n-k)}{}_{\alpha\text{-critical}} \quad (30)$$

To check the results simply, we can see the probability value if the probability value is greater than .10 than it shows that the model is not significant and vice versa. In our model the probability value lesser than .10 is establishing that model is significant.

4.5.9.4 **Autocorrelation detection**

One of the major problems in multiple regression models is presence of autocorrelation. It represents the degree of similarity between the given series and its lagged version over successive time intervals. It is same as estimating the correlation between two different time series, the difference here is that the two time series are used, once it is used in its original form and once in its lagged form, so in simple words a correlation is estimated between the time series and its lagged time series[399].

Durbin Watson test is used to calculate autocorrelation, this test ranges from 0 to 4, a value approaching 0 is showing positive autocorrelation, while the values approaching 4 shows negative autocorrelation, the acceptable range for no autocorrelation is from 1.5 to 2.5. In our test results the value is 1.65[400], which puts it in acceptable range, thus indicating no correlation in the model.

4.6 Summary

The results from the panel analysis have given us insight about three major areas related to supply chain. Since the results are from the three major German automotive companies, it implies that the results are typically valid for German Automotive industry. The results from the relation in inventories show that all three level of inventories have either significant impact or partially significant impact. Finished goods inventories contribute less towards supply chain efficiency, while raw material inventories have slightly positive impact, which implies that keeping more inventories as a buffer stocks will

[399] http://www.investopedia.com/terms/a/autocorrelation.asp Seen on May 2016

[400] http://help.sap.com/saphelp_scm70/helpdata/en/c3/657dc439d811d3982b0000e8a49608/frameset.htm Seen on May 2016

increase efficiency in the supply chain. This is mainly because of the reason that higher raw material inventories will make firms less vulnerable to the shocks. The work in progress has negative impact on supply chain efficiency showing that rise in in/house operations have negative impact on supply chain efficiency, this is also clear from the analysis of Volkswagen AG supply chain in chapter 3.

Both |DdP and DdS are positive, showing that either producing in home or producing near the markets, under mass customization this impacts the supply chain efficiency normally. The DDP impact more positively in efficiency as compared to DDS, thus it is more feasible to produce near the markets as compared to producing in home country and delivering the whole vehicle to the market. There are many reasons for the support of this result, producing near the market, not only affect the logistics costs but also let the producer to adjust according to the local market conditions.

Issues in downstream supply chain, such as delivery time, dealership facility, fairness of price etc. has a strong positive impact on supply chain efficiency with respect to mass customization. This relation is also highly significant also.

5 Mass customization and issues of downstream supply chain

This chapter addresses the third research question of this study, i.e. how mass customization is affecting the efficiency of downstream supply chain. This question is already been addressed by the author in doctoral journey, a scientific paper has already been published[401]. Here the research paper is presented below. The paper investigated the question for the same automotive companies (addressed in previous chapters). However Volkswagen AG was not addressed in the paper, therefore the analysis on Volkswagen AG would be described in section 5-3.

5.1 Abstract

"Automotive companies have successfully adopted mass customization. However, this production method has complicated the sales process as the customer has to go through a lot of steps to specify the product. Thus, it is important that the sales process is modified to make the producer–buyer interaction efficient in mass customization. There is no study that examines whether the modifications in the sales processes of the automotive industry are according to the needs of mass customization. In this context, we investigate this relation for two leading automotive companies, for the customers of the USA, from 2008 till 2015. By applying statistical calculations, we observe that the increase in mass customization has actually declined customer satisfaction of the sales process. Hence, there is a further need to modify the sales process according to the needs of mass customization. Otherwise, the long-term success of mass customization of a car manufacturer is at risk.

5.2 Introduction

Mass customization has replaced or supplemented mass production in many parts of the world[402]. The main focus of this production system is to meet the individual customer demand with minimal loss of efficiency[403]. Thus, it demands sophisticated linkages. Since customer and buyer rely on each other to

[401] Khan, A., & Haasis, H. D. (2016). Producer–buyer interaction under mass customization: analysis through automotive industry. Logistics Research, 9(1), 17

[402] Cox, W. M., & Alm, R. (1998). The right stuff: America's move to mass customization. Economic Review-Federal Reserve Bank of Dallas, 3.

[403] Liu, G., & Deitz, G. D. (2011). Linking supply chain management with mass customization capability. International Journal of Physical Distribution & Logistics Management, 41(7), 668-683.

create the desired product, mass customization demands two-way communications (from buyer to producer and from producer to buyer) instead of one-way communication (only from producer to buyer)[404]. The communication between producer and buyer is mainly achieved through the sales process. Under mass customization, the latter is involved in a lot of processes, i.e., picking choices, opting service, filling forms. If the sales process fails to transfer customer's idea to the producer or it further confuses the person, then the success of mass customization is at stake. Hence, the efficiency of the sales process is of vital importance in the mass customization. In modern times, the automotive industry has propelled rapidly toward mass customization. If we consider producer– buyer linkage within the automotive industry, we recognize that customer to producer interaction is more complicated here. Automotive is usually bought through a dealer, and customers rarely want to order their car online. So the dealer has to explain the options, the possible combinations and the different packages available to the customers. Thus, the sales process becomes much more complicated for the dealer as they are the main messengers between the producer and the buyer. It is important that they are trained properly to guide customers during the buying process. Another aspect of the sales process in the automotive industry is that customizing a car also takes time as many steps, e.g., painting, assembling and delivering processes are according to customer choices. Hence, it requires time which may lead to the decrease in the satisfaction of the customer. All these factors demonstrate that adoption of mass customization is much more complex in the automotive industry than in other small products industries[405]. However, despite all these challenges, many automotive companies adopted mass customization quite successfully. Since mass customization complicates the sales process for automotive companies, it is important to investigate whether the automotive companies have modified the sales process according to the needs of mass customization or not. As here exists no such study, we investigate the association between mass customization and sales process efficiency for two leading automotive companies (which are quite successful in the adoption of mass customization) and evaluate that whether they are also successful in the modification of the sales process. To address the problem in more detail, we analyze the existing literature in Sect. 5.1.3 In Sect. 5.1.4; we investigate the problem through a statistical investigation of two automotive companies. In Sect. 5.1.5, we discuss the results of the statistical calculations. Last, we conclude our work and give an outlook on future studies in Sect. 5.1.5.6.

[404] Mittal, V., Katrichis, J. M., & Kumar, P. (2001). Attribute performance and customer satisfaction over time: evidence from two field studies. Journal of Services Marketing, 15(5), 343-356.

[405] Pollard D, Chuo S, Lee B (2011) Strategies for mass customization. J Bus Econ Res 6(7):77–86

5.2.1 Literature analysis

Although mass customization provides customer with large number of varieties, this does not automatically generate an added value for the customer[406]. It is observed that high level of options offered to customer may confuse him instead of increasing his satisfaction. It may also lead to the production of the product which is not desired by the customer[407]. Moreover, it is investigated that the relationship between numbers of choices offered and perceived satisfaction can be bidirectional. Customers can be overwhelmed by the high number of choices while in some cases it is found that customer may find large assortments as frustrating[408]. Selection process can be complicated long, and customer might experience an uncertainty. Sales management is one of the tools to get customer out of this frustration and uncertainty, and it should be designed to simplify the relation between customer and producer[409]. In other words, we can say that mass customization requires customized marketing strategies. It needs sophisticated changes in the sales process which should be focused to comfort customer during configuration process, and mass customization is thought to be a step toward realization of mass customization[410]. There are many literatures which emphasize on the different production strategies under mass customization. However, research on how customers will co-design with producer is rare[411]. Companies claim to produce thousands of different products under mass customization, but the question arises that do these companies translate their ability to produce thousands of products into shopping and purchasing attitude of customer. Thus, in the current study, the main focus is to investigate customer satisfaction perceived from the sales processes, while the adoption of mass customization. To make our analysis more specific, we are addressing this issue for the automotive industry. By considering mass customization under automotive industry, we figured out that relation between producer and buyer becomes more complex here. The main reason is that in the automotive industry, this relation is distorted by the third party ‘‘dealer’’. Since the relation is not direct, it needs sophistication. Moreover,

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[406] Quelch, J. A., & Kenny, D. (1994). Extend profits, not product lines. Make Sure AllYour Products Are Profitable, 14.

[407] . Huffman C, Kahn BE (1998) Variety for sale: mass customization or mass confusion? J Retail 74(4):491–513

[408] Kahn, B. E. (1998). Dynamic relationships with customers: High-variety strategies. Journal of the Academy of Marketing Science, 26(1), 45-53.

[409] Piller, F., Koch, M., Moeslein, K., & Schubert, P. (2003). Managing high variety: how to overcome the mass confusion phenomenon of customer co-design. In Proceedings of the Proc. 3rd Annual Conf. of the European Academy of Management (EURAM 2003), Milan, Italy.

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[411] Piller, F., Koch, M., Moeslein, K., & Schubert, P. (2003, April). Managing high variety: how to overcome the mass confusion phenomenon of customer co-design. In Proceedings of the Proc. 3rd Annual Conf. of the European Academy of Management (EURAM 2003), Milan, Italy.

since it takes time and complexities to produce a car, so in-time delivery also becomes a problem. Thus, various such factors, e.g., dealers, dealership facility, selling management, delivery time, complicate the sales procedure[412]. It is also investigated that different e-services (which include different online services of ordering, complaining, configuring, etc.) could be used to facilitate customer in mass customization process[413]. However, in the case of automotive customers, it is observed that customer relies more on dealer as compared to these e-services[414]. So customer value achievement under mass customization in automotive industry is of greater concern[415]. Importance of customer satisfaction from sales process for the automotive industry has been emphasized in the literature also[416]. There is a study about Portugal that reveals different factors behind customer satisfaction for automotive industry. It investigates the relation between producer and customer via qualitative analysis, for three automotive companies: Toyota, Ford and Renault. It emphasizes that selling behavior, supportiveness provided, after sales services and perceived quality have a significant role toward customer satisfaction[417]. Sales strategies should be given importance to make the customer more satisfied. It should not be ignored that the producer to buyer interaction is one of the major concerns of the supply chain; this part has an important role in the achievement of getting higher customer value and has got a significant place in the modern supply chain[418]. Moreover, it should also be noted that mass customization has given different results to different companies. Volkswagen AG claims to save $1.7 billion annually[419], while Opel lost $747 million in 2011[420]. This is due to different operational strategies[421]. So, sales modifications for automotive industry under mass customization are a matter of concern. The above-mentioned

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[420]http://gmauthority.com/blog/2012/12/gm-should-have-dumped-opel-when-it-had-the-chance-opinion-desk/ Seen on May 2016

[421] Pollard D, Chuo S, Lee B (2011) Strategies for mass customization. J Bus Econ Res 6(7):77–86

arguments lead to a question that whether in the automotive industry has the sales process been modified according to the needs of mass customization. If we look into the literature, we cannot find any study which specifically deals with this issue. The purpose of this paper is to fill this literature gap. Our focus will be to consider the implications of mass customization on producer–buyer relationship in downstream supply chain. Hence, we will investigate whether modifications adopted by car companies are sufficient to meet the challenges of mass customization or not.

5.2.2 Methodology

To address the research problem, we are taking two cases from the automotive companies. The selected companies have adopted mass customization successfully, and this will help us to figure out that whether the companies also focused on the modification of downstream supply chain. Our focus will be on the quantitative analysis. First, we fix measures for the satisfaction of customer regarding the buying process and for the mass customization itself. Based on these data, we perform a statistical analysis.

5.2.3 Data analysis

In the current study, we have chosen to analyze the data for US automotive customers of BMW AG and Mercedes-Benz from 2008 till 2015.

5.2.3.1 **Measuring the extent of mass customization**

Mass customization can be measured by investigating the number of available options. Automotive companies are providing different options to customers for tailoring their products. However, for a customer, the selection of advanced options like driver assistance package and different sports packages is much more difficult than color selections. So, most automotive companies provide yes/no options for advanced packages, while for the upholstery, trim and exterior colors different choices have to be opted. The measure of the extent of customization is called Customization extent (CE). It is comprised of the number of options available for trim, paint, packages, upholstery, wheels, etc.

$$CE=\prod_{x_i=1}^{7}\prod x_i \qquad 31$$

where x1 = no. of options for paint, x2 = no. of options for upholstery, x3 = no. of options for trim, x4 = no of options for wheel, x5 = no of individual options available, x6 = no of additional packages, x7 = no. of steering wheel options. For both of the selected companies, customers are allowed to customize the car through phenomena known as ‘‘Build your own car’’. We evaluated CE for different models of each company, i.e., for Mercedes-Benz the evaluated models are C class, E class, G class, Cls class

and S class, while for BMW AG series 7, 6, 3 and 1 are used. It is found that for each company in each year, customization options are almost same for all models. However, to get more valid results, we evaluated CE for every model separately and took the averages to get the final values, shown in Table 1 in ‘‘Appendix’’.

5.2.3.2 **Satisfaction perceived by the customer**

To measure customer satisfaction regarding the sales process, we follow the approach introduced in the J.D. Power studies[422]. There, the authors constructed a number of indicators, which describe different aspects of automotive companies. One of the significant indexes developed by the study is Sales satisfaction index (SSI), which gives a comprehensive analysis of the new-vehicle purchase experience from the customer perspective response with respect to purchase, delivery, sales and price. We employ the SSI index to measure for satisfaction given two different categories: buyers (who ultimately buy the product) and rejecters (who due to some of the reason leave the product). In accordance with the J.D. Power studies, we utilized a weight of 51 % for buyers and 49 % for rejecters[423]to compute SSI for US automotive customers via the formula shown in Eq. 2. Since SSI is constructed by using a large amount of data, it allows to generate a meaningful picture of customer satisfaction regarding the sales process.

SSI=f(Working out of deal, Delivery process, Dealership facility,sales person, Price Fairness, Facility, Inventory, Experience Negotiations)

The weights for subcategories proposed in JD studies[424] are given in Table 2, shown in ‘‘Appendix’’. We like to note that all variables shown in Table 2 are impacted by mass customization. Since mass customization adds a lot of complexity to the buying process, it demands modern dealership facilities, informed sales persons and efficient dealing. Similarly, delivery time is important in the case of mass customization because cars are mainly assembled after the placement of the customer’s order.

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[422] J.D. Power Associates press release (2011). http://businesscenter. jdpower.com/news/pressrelease.aspx?ID=2011199. Seen on May 2016

[423] J.D. Power Associates press release (2011). http://businesscenter. jdpower.com/news/pressrelease.aspx?ID=2011199. Seen on May 2016

[424] J.D. Power Associates press release (2011). http://businesscenter. jdpower.com/news/pressrelease.aspx?ID=2011199. Seen on May 2016

5.2.4 Measuring relation between CE and SSI

Data organized for CE and SSI are shown in Table 3, in ‘‘Appendix’’. After getting quantitative data on both indicators for the mentioned companies, we can use statistical techniques to analyze the relation between the two. To measure the link between the two variables, we utilized the Spearman rank correlation[425]. This test is without any limitations; thus, it can give us meaningful details regarding the interdependency of the variables.

5.2.4.1 Spearman ranks correlation test

Spearman rank correlation is used to investigate the strength of the link between two data sets. It is an alternative to linear regression and correlation. There are several advantages of using Spearman rank. Most importantly, it helps to get rid of outliers. The null and alternative hypotheses for the test are as follows:

H0 There is no relation between two variables

H1 There is relation between two variables

The Spearman rank correlation can be calculated with the help of the following formula:

$$\boldsymbol{r = 1 - \frac{6\sum di^2}{n(n^2-1)}} \qquad \textbf{32}$$

Where we use, $di = CE_i - SSI_i$, for respective years i and n represents the number of observations for SSI or CE The value of the coefficient “r” ranges from -1 to +1. If the value turns out to be zero, we will accept the null hypothesis otherwise reject it. The r value of -1 suggests that the relation is strongly negative while +1 suggests that two variables are correlated strongly positive[426].

5.2.4.2 Validation of the estimation

In statistics, it is important to validate the result obtained from any test. Here, we apply a significance test significance to determine whether the results obtained from the spearman rank correlation, regarding the association between mass customization and sales process efficiency are valid or not. Most

[425] McDonald, J. H. (2009). Handbook of biological statistics (Vol. 2, pp. 173-181). Baltimore, MD: sparky house publishing.

[426] Zar, J. H. (1972). Significance testing of the Spearman rank correlation coefficient. Journal of the American Statistical Association, 67(339), 578-580.

commonly the T-test is used for this purpose[427]. We apply T-test with the following null and alternative hypothesis:

H_0 = There is no correlation between Mass customization and sales efficiency in the population

H_1 = There is correlation between Mass customization and sales efficiency in the population

With the above mentioned hypothesis, the next task is to evaluate T-test via the formula:

$$t = r/\sqrt{(1-r^2)/(n-2)} \quad (33)$$

Eq. 4 where r is the spearman coefficient calculated from Eq 3 and n represents the number of observations for SSI or CE

The results of the t-tests are checked with the help of rule of thumb for this test, which states that "If the T-value is greater than $\left|2\right|$, it shows that relation between the two variables is statistically significant so we can reject the null hypothesis and vice versa"[428]. Rule of thumb is estimated for a 95% confidence interval

5.2.5 Results

Utilizing the data and methods from last sections, we obtain the table 5-1. Here r statistics are calculated using eq 3 while the t statistics are calculated eq 4.

Test	Company	R	T-value	Interpretation
Spearman rank correlation test	BMW AG	-0.64	-2.04	Strong and significant negative relation
	Mercedes-Benz	-.29	-.28	Week and insignificant negative relation

Table 5-1: Results from spearman rank correlation test
Source: Author's calculation

[427] Solihull, N. (2001). Mass customization: a long march. The Economist: Keeping the Customer Satisfied, 67-19.

[428] Lind, D. A., Marchal, W. G., & Mason, R. D. (2001). Statistical techniques in business and economics. McGraw-Hill/Irwin.

As shown in the table, the results from the test are similar for both companies regarding respective signs but are different in impact and significance. Overall, the results are negative for both companies. This shows that the association between mass customization and satisfaction regarding the sales process is negative. We cannot say that the rise in one variable cause decline in other, as correlation does not mean causality. However, we can say that with the overall rise in mass customization producer-buyer linkage weakened. This implies that the sales process is not modified according to the needs of the new production system in both automotive companies.

The results of the two companies are different in strength and significance. In the case of BMW AG, we observe that company has a vast program for carrying out mass customization. The company has developed various options in design and combination. However, we see that with the increase in the mass customization, the satisfaction from the sales process has declined significantly. There is a strong negative and significant relation between mass customization and sales process efficiency, which shows that the sales process was not modified accordingly. The results from Mercedes-Benz are not different from BMW AG. Yet, unlike BMW AG there is weak and insignificant negative relation between the mass customization and sales process efficiency. This implies that Mercedes-Benz should also improve the sales process efficiency. However, it must be noted that the customization program of Mercedes-Benz has not declined the customer satisfaction from sales process as much as in the case of BMW AG.

Hence, the above-mentioned results imply that the modification of the sales process is not sufficiently elaborated. It should be noted that in calculating SSI, delivery time has also been taken into account. With the advance in customization, it becomes difficult to customize the product in time, which causes unrest in the customers. Furthermore, with the increase in delivery time customer preference and choices may change leading to decrease in his level of satisfaction. Another important reason behind these results can be involvement of the third party. As the above-mentioned studies are for U.S it must be noted that most people prefer to buy through a dealer instead of buying online[429]. The dealer has the responsibility mostly to read the customers mind and transfer it to a producer. Thus, if the dealer fails, it results in customer dissatisfaction regarding the sales process or even in the dissatisfaction regarding the mass customization.

[429] McDonald, J. H. (2009). Handbook of biological statistics (Vol. 2, pp. 173-181). Baltimore, MD: Sparky House Publishing.

Moreover, we like to note that these results do not mean that mass customization is unsuccessful in the mentioned companies; it might be possible that two companies are very efficient in the adoption of mass customization from different prospects; however, the companies have not sufficiently modified the sales process.

5.2.6 Conclusion and future outlook

Mass customization attracts customers but at the same time, it complicates the downstream supply chain. The main reason for this is that in mass customization the producer has to read the customer mind, a phenomenon which influences the producer–buyer relation. There is enough literature which shows how production should be modified to meet the needs of mass customization. However, the importance of modifications in the sales procedure is ignored. The question is raised in this study that whether in the automotive industry the modifications carried out in the sales procedure are enough to meet the requirements of mass customization. To investigate this question, we considered the cases of two automotive companies, BMW AG and Mercedes-Benz. We evaluated the quantitative data for the customers of the USA for both companies from 2008 to 2015. Firstly, we developed an indicator to measure the extent of customization (CE). Secondly, to measure the sales process efficiency, we used the SSI developed by J.D. Power studies. After organizing data, we used statistical tests to compute the correlation between customization extent and efficiency in the sales process via the Spearman rank correlation test. Moreover, we applied the T test to check the significance. The results obtained were negative for both companies which imply that with the increase in mass customization the efficiency in the sales process has declined, or in other words, producer–buyer linkage has weakened. However, the results of Mercedes-Benz are better than of BMW AG. The former has weak and insignificant association between SSI and CE, while the latter has strong negative and significant relation. Yet, both companies need to consider further modifications in the sales process. Literature focuses a lot on modifications in the production procedure, while there is hardly any study which brings out the importance of sales management under mass customization or suggests how sales procedures should be modified to meet mass customization challenges. To fill this gap, this paper brings out that sales procedures modifications under mass customization should be given significant importance. The empirical analysis showed that automotive companies are not modifying the sales procedures enough to meet customization challenges. Producer to buyer interaction should be made as simple as possible. There is need to bring out more sophisticated changes in sales procedures under mass customization. Many sales criteria like simple selection process, delays in delivery, price fairness and dealer's availability are the areas to focus on, apart from the different mass customization production techniques. Moreover, further

work can be done to validate the results of this study through expert interview, analyzing the above-mentioned variables for forecasting purposes or using other statistical techniques".

5.3 Case of Volkswagen AG

The analysis done until section 5.2 is from the paper by the author. The paper however didn't include Volkswagen AG. To make this analysis more complete in this section the same method (used in section 5.2) is applied to the third case of our study, Volkswagen AG.

5.3.1 Data establishment

Mass customization is calculated for Volkswagen AG also, using the formula given in equation 31, while SSI for the company is established using the J.D. power study[430]. The data obtained is then used for the tests

5.3.2 Measuring of relation (test and Validation)

The relation between SSI and Mass customization is calculated using correlation test, discussed in equation 32. The statistics from the test are then validated through t test, mentioned in equation 33. The results obtained from these tests are shown in table 5-2.

Test	Company	Correlation test- r	T-value	Interpretation
Spearman rank correlation test	BMW AG	-0.64	-2.04	Strong and significant negative relation
	Mercedes-Benz	-.29	-.28	Week and insignificant negative relation
	Volkswagen AG	-.40	1.18	Moderate insignificant negative relation

Table 5-2: Comparison of results
Source: Authors calculations

[430] http://businesscenter. jdpower.com/news/pressrelease.aspx?ID=2011199. Seen on May 2016

The result from the table shows that they are in line with the results of the other companies. Thus strengthening the results deduced from section 5.2, there is negative association between mass customization and SSI, this relation is moderately insignificant. The results from all three companies show negative association between mass customization and issues in downstream supply chain.

5.3.3 Conclusion

The results from Volkswagen AG are also supporting the results already mentioned in section 5.2.6, with the increase in mass customization the issues in downstream supply chain has increased, and customer satisfaction from the sales process has declined.. This trend may not influence the impact of mass customization on profit in the short term, but because of this trend, the long term success of mass customization is at stake.

6 Conclusion and Recommendations

Mass customization is trending among many industries as it increases the customer value. Due to uncertainty and highly dynamic nature of mass customization, it requires significant changes in the supply chain structure. The traditional supply chain practice does not fit the mass customization production method. As a result, companies adopting mass customization have completely transformed their supply chain in the last couple of years. This has in many cases lead to the risk-bearing environments. In automotive industry, mass customization is increasing rapidly from last decade; hence, the Supply chain policies have also undergone many changes. New production methods have been introduced which resulted in new strategies and policies to manage the supply chain. The trends of modularity, outsourcing, and globalization in production are increasing, which has changed the face of supply chain management.

Since the suppliers are also involved in the customization process, their value has also been enhanced with mass customization. In the modern supply chain of mass customized products, the supplier adds 70 to 80 % of the value chain. These suppliers are mostly located in the supplier centers or supplier parks near the assembling plants and are providing just in time deliveries. This has not only increased complexities but also the risks have become profound. The events in the last couple of years show that many times in modern production, a disruption have been caused by the supplier and have resulted in production halt for the OEM. Keeping this in the background this study is focused to investigate modern supply chain practices which are established in order to carry out mass customization. In this regard, different policies and practices within the modern automotive industry are analyzed in order to investigate the research question that which supply chain practices are more efficient in the German automotive industries.

Literature regarding the issue is analyzed in chapter 2; it is observed that although there are some studies related to German automotive industry but they are mostly covering the issues on the plant level, there were not any studies which focus on analyzing the issue on the industrial level or do any comparison between the companies. To fill this research gap this study focused specifically the supply chain macro policies, which are targeted to carry out mass customization. Moreover, since there is no study with the comparative analysis of the companies within the industry, this study compares three German companies Mercedes-Benz, BMW AG and Volkswagen AG; such comparative analysis can help to differentiate between risky and efficient policies. The companies are investigated through Mixed-Method approach. This approach uses both qualitative and quantitative analysis.

To investigate the policies related to supply chain management a qualitative supply chain analysis is carried out in chapter 3. Case studies analysis is carried out on three selected companies. Firstly a supply chain structure is developed from literature, and then all three companies are investigated through this structure. This developed supply chain structure considers three main aspects of the supply chain; management components, business processes and supply chain. It was observed through analysis, that while Mercedes-Benz and BMW AG preferred to outsource most of the functions with the beginning of mass customization, Volkswagen AG preferred to keep most of the operations in-house until 2010. Due to this preference for outsourcing, it has been observed that in modern automotive industry companies are totally dependent upon the supplier. This has increased risk in the supply chain and has led to a number of incidents in last decade. Moreover, the automotive companies are losing their expertise in automotive production while this expertise has been transferred to the suppliers. Thus, in modern production, the supplier has more information about the car than the OEM.

Further analysis of policies for the three companies showed that all three companies manage their relationships with suppliers differently. Mercedes-Benz controls its supplier more; it keeps check on safety stock levels at the supplier and decides the inventory level at the supplier site. Moreover, suppliers are directed to make investments (supplier parks) near the Mercedes-Benz assembling plants. At BMW AG, the supplier management is also comparable to Mercedes-Benz, but BMW AG prefers to develop partnerships with the supplier, the supplier has to inform BMW AG at regular intervals about their safety stock levels. In addition to this, the supplier centers (instead of supplier parks) are developed near the production site by BMW AG instead of being developed by suppliers. In the case of non-compliance or non-delivery, all the losses have to be suffered by the supplier. Thus although BMW AG, does not directly control a supplier (by deciding the safety stock levels or making them invest near the production sites), it controls them more indirectly; for instance, in the case of non-delivery, all losses to the OEM are to be suffered by the suppliers. The production site of the supplier is owned by BMW AG (unlike in Mercedes-Benz where supplier parks are developed by the suppliers). These small differences in policies have lead BMW AG ahead of Mercedes-Benz in supplier relationship management, as BMW AG has topped in the indicators (SuRe index and WRI) related to supplier management. It is probably due to the reason that supplier feels less controlled while they are controlled more indirectly. Moreover, the risk assessment system at BMW AG is well developed.

As compared to BMW AG and Mercedes-Benz, Volkswagen AG has developed less expertise in outsourcing. The major reason is that company has a major focus on in-house operations until 2008, after 2008 outsourcing increased in the company, but not like BMW AG and Mercedes-Benz. Due to this, the company has less experience to manage relationships with suppliers (while outsourcing) and hence

has experienced worst experiences. As the suppliers are not much involved in the production from the long-time, thus the company has not treated them on the equal levels. The behavior has resulted in the major incidents that the company has suffered

To establish that which of policies are better and results in more efficacies, a comparison of supply chain performances of all three companies is also done in this chapter, using different indexes and number of incidents that have happened. It is figured out that BMW AG has best supply chain practices, while the practices at Mercedes-Benz are near best. These two companies also show remarkable results in index comparison. Since BMW AG and Mercedes-Benz have a higher affinity for outsourcing they treated supplier as a partner with mutual regulations. The case of Volkswagen AG was opposite; it has not only low performance on supply chain indexes, its supply chain policies were also different from the other two companies, outsourcing was never preferred by the company in history, so when the company opted for outsourcing recently for some mass customization operations, it lacked behind due to less expertise. Therefore, the chapter established that, if the outsourcing is not managed with sufficient mutual policies, (and supplier feels to be bullied by the OEM) it results in the inefficiencies. Furthermore, the history shows that all the three companies have suffered from dependence in supply chain once or more times, as all three have, once or more times, halted their production due to this dependence. Interruptions caused by tier 2 suppliers, have halted module tier 1 suppliers in a number of incidents that happened. These results suggest that OEM needs to monitor for niche supply chain of the supplier as well.

To investigate further issues related to inventories, distributional policies and downstream issues, a quantitative analysis is carried out in chapter 4. For this analysis, data from the automotive industry is taken from 2007-2015, as this is the time period in which the mass customization becomes more prominent in the automotive industry. The main source of data is financial reports of the companies and broachers. The data was investigated using Fixed Effect test under Panel analysis.

Firstly, a model is developed with the help of literature, which represented the impact of different variables on supply chain efficiency under mass customization. The model was then investigated with Panel data analysis. The variables of the model included inventories, network distribution and issues of the downstream supply chain. The results achieved are significant and without autocorrelation. For investigating the impact of inventories, the impact of three types of inventories, raw material inventories, work in progress and finished goods inventories was estimated on supply chain efficiency under mass. The results suggest that increasing the raw material inventories is impacting positively to supply chain efficiency under mass customization, while the work in progress inventories and finished goods

inventories should contribute negatively to supply chain efficiency under mass customization. This suggests that under the implementation of JIT, the high buffer stock at OEM contributes positively towards profit, as it helps to mitigate shocks. Therefore, raw material inventories in the form of buffer stock should be increased, while work in progress should be decreased or in other words, outsourcing should be increased while the finish good inventories should be minimized. Hence the results show that outsourcing is contributing positively to supply chain efficiency, suggesting the same results as obtained from chapter 3. However, outsourcing needs to be managed with the policies, which can minimize the risks associated with it.

Another important factor investigated through the quantitative analysis is the network distribution. It is investigated that is it more profitable for the company to produce in the home country and distribute the final vehicle world markers or is it better to assemble near the markets. The result from the analysis shows that it is more profitable to produce near the markets instead producing in the home country and delivering to the final destination. This is due to the reason that when the producer is near the market, it understands the local conditions more accurately and thus supply chain could be managed in a better way. The result of downstream supply chain issues suggests that issues like distribution, delivery time, dealership response, the experience of negotiations, price fairness etc. have a strong and significant impact on supply chain efficiency under mass customization. An improvement in the mentioned downstream issues ensures that the mass customization would result in higher profits.

Moreover, since the literature suggests that if mass customization is not parallel with the efficient changes in downstream segment of the supply chain (producer-Buyer linkage), it may confuse the customer. Therefore in chapter 5, a statistical correlation analysis is established to investigate that whether in the modern supply chain the sales process is modified to adjust needs of mass customization. It was found out that mass customization has increased the issues in the downstream segment of the supply chain, which is impacting mass customization efficiency. The relation between mass customization extent and issues of the downstream supply chain was investigated for all the three companies. It was found that for all three companies increase in mass customization has resulted in a decrease in downstream supply chain performance, or in other words, with the increasing extent of mass customization the issues in the downstream supply chain have increased and thus the customer satisfaction from the sale process has declined. This result is same for all the three companies, which is quite understandable as with the mass customization prices rise, delays in delivery could occur, responsibility on dealership increases etc. However, since we already discussed that literature suggests that mass customization could decrease customer satisfaction from the whole process (opposite to the task for which it is themed) if the downstream supply chain is not managed properly. Thus, the results provide deep insight

into the problem which is ignored by the automotive companies. For efficient mass customization, the issues in the downstream supply chain should be managed efficiently.

Overall, the study points out some main deficiencies in the modern automotive supply chain management. Due to the higher involvement of the supplier, the automotive companies are losing control over the supply chain, although outsourcing is profitable, but it needs to be managed carefully otherwise there are high risks (associated with not only first tier supplier but also with the second and third tier supplier). The relationship with the supplier should be managed in such a way that supplier feels an equal responsibility and happiness with the product successes. The inventories at the raw material level or buffer stocks should be increased to avoid risks in the supply chain; the production near the markets should be promoted. While the efficiency in the downstream supply chain should be increased.

Since the study was carried out only the German companies, it takes into account only the hindrances and challenges faced by the companies in German laws, culture, and politics. The findings may not apply to the companies from the other countries, which face different laws and regulations. Moreover, there is the difference in the sizes of three discussed companies, although the companies analysed are implementing comparable policies, however, due to the sizes the supply chain policies also differ.

This study is highly beneficial for not only the OEMs but also for the suppliers, the study could be beneficial in the following ways

- It can help companies to devise policies while managing mass customization
- It would help companies to develop relationship with the suppliers
- It would be helpful to devise policies related to outsourcing and modularization
- It brings a comparison of different risk filter methods and could help companies to develop risk related policies
- It helps the OEM and suppliers to develop policy related to inventories
- It helps the OEM to develop policy related to network distribution
- It highlights the importance of downstream supply chain issues
- It brings out different methods used to control, plan, and manage the supply chain network business process and management components, this would be highly beneficial for not only the automotive industry but also for the other industries, specifically while establishing a policy related to supply chain management

The study is carried out with full effort of the author, in light of this study future research can be carried out with following prospects

- An important index to measure mass customization is completely developed by the author by analyzing large data set from company broachers. This developed index can be used to investigate further issues in the supply chain. It is developed by careful examination of broachers of different models of car companies for 8 years, can be used in different future researches. This index can help in measuring quantitative issues related to mass customization.
- Moreover, since a structure and model was developed in both quantitative and qualitative analysis, these can be used in future researches on other companies as well.
- Another interesting topic related to mass customization is invention of 3D technology in automotive industry, which can change the structure of supply chain as well. A future research on this topic can also be interesting.

Appendix

Table A-I: Data for Mass customization

Year	Mercedes-Benz	BMW AG	Volkswagen AG
2007	5046	35500	752
2008	5917,5	35568	1520
2009	9655,75	23490	1044
2010	13806,6	106821	1176
2011	7298,6	486248	912
2012	15789,6	665348	661002
2013	55900,32	2098880	1688712
2014	89784	1663214	1560194
2015	427707,2	1695157	2510928

Table A-II: Data for SSI

Year	Mercedes-Benz	BMW AG	Volkswagen AG
2007	890	881	800
2008	897	884	853
2009	877	861	780
2010	815	799	790
2011	701	677	709
2012	717	714	665
2013	728	712	700
2014	761	727	713
2015	749	727	712

Table A-III: Raw Material Inventories

Year	Mercedes-Benz	BMW AG	Volkswagen AG
2007	1741	632	2100
2008	1727	596	2009
2009	1517	536	2030
2010	1509	663	2494
2011	1802	704	3429
2012	2137	786	3506
2013	2011	843	3716
2014	2409	918	3941
2015	2643	1004	3090

Table A-IV: Work in progress Inventories

Year	Mercedes-Benz	BMW AG	Volkswagen AG
2007	1907	871	1521
2008	1880	803	1656
2009	1626	542	1590
2010	2002	683	1837
2011	2451	908	3324
2012	2292	827	3504
2013	2275	850	3096
2014	2936	944	3552
2015	3371	1098	3057

Table A-V: Finished goods inventories

Year	Mercedes-Benz	BMW AG	Volkswagen AG
2007	10343	5846	10902
2008	13066	5891	12396
2009	9666	5477	8842
2010	10974	6420	10819
2011	12737	8026	17383
2012	13235	8112	18015
2013	13028	7892	18284
2014	15412	9227	20156
2015	17609	8969	22000

Table A-VI: Distributional Distance in Production

Year	Mercedes-Benz	BMW AG	Volkswagen AG
2007	1,5	1,4	8,52
2008	1,486789	1,721781	9,256566
2009	1,513432	2	10,12223
2010	0,890252	2,354558	11,55365
2011	6,82926	4	11,30144
2012	3,70674	5,817522	11,76495
2013	4,241823	8,922556	11,93535
2014	4,719126	8,98825	11,62179
2015	4,67	8,9	10,86518

Table A-VII: Distributional distance in sales

Year	Mercedes-Benz	BMW AG	Volkswagen AG
2007	17,01	20,44651	2,195
2008	17,38472	20,46748	2,748377
2009	15,20017	18,09021	2,370307
2010	18,81964	19,81989	2,046505
2011	15,3975	21,14134	3,009045
2012	19,52572	19,7364	3,455336
2013	22,02557	18,10701	3,728523
2014	20,44264	18,27211	4,184051
2015	20,3	17,66734	4,277408

Table A-VIII: Variables weigh in SSI

Variable	Rejecter/buyer	Weight (%)
Working out deal	Buyer	17
Sales person	Buyer	13
Delivery process	Buyer	11
Dealership facility	Buyer	10
Sales person	Rejecter	20
Fairness of price	Rejecter	12
Facility	Rejecter	6
Inventory	Rejecter	6
Experience negotiation	Rejecter	5

Source: Table constructed from the information in J.D. Power Associates

Table A-IX: Data in the model form

Year	DYDMC_?	LR_?	IF_?	LSSI_?	LW_?	LDP_?	LDS_?
1-2008	-3.02467	-14	3823	7	-27	-0.01321	0.37472
1-2009	-0.70006	-210	-3400	-20	-254	0.026643	-2.18455
1-2010	1.242155	-8	1308	-62	376	-0.62318	3.619464
1-2011	-0.08236	293	1763	-114	449	5.939008	-3.42214
1-2012	-0.09434	335	498	16	-159	-3.12252	4.128219
1-2013	-0.0096	-126	-207	11	-17	0.535083	2.499854
1-2014	0.05451	398	2384	33	661	0.477303	-1.58293
1-2015	0.006135	234	2197	-12	435	-0.04913	-0.14264
2-2008	-48.3971	-36	45	3	-68	0.309781	0.11832
2-2009	0.052327	-60	-414	-23	-261	0.2838219	-2.54727
2-2010	0.057662	127	943	-62	141	0.974558	1.895681
2-2011	0.007706	41	1606	-82	225	2.05442	1.161448
2-2012	0.001435	82	86	37	-81	1.747522	-1.240493
2-2013	-0.00021	57	-220	-2	23	3.305034	-1.62939
2-2014	-0.00262	75	1335	15	94	0.055695	0.285096
2-2015	-0.10334	86	-258	0	154	-0.08825	-0.50477
3-2008	0.236979	-91	1494	53	135	0.736566	0.553377
3-2009	9.407563	21	-3554	-73	-66	0.86566	-0.37807
3-2010	40.04545	464	1977	10	247	1.431424	-0.3238
3-2011	-15.6439	500	6564	-81	1487	-0.25221	0.962539
3-2012	0.000344	77	632	-44	180	0.463507	0.446291
3-2013	0.000168	210	269	35	-408	0.170399	0.273187
3-2014	-0.00798	225	1872	13	456	-0.31356	0.455528
	-1.1E-05	-851	1844	-1	-495	-0.75662	0.093356

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