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The Development of a Research Framework for Inventory Performance Improvement of the Automotive Manufacturing Industry: Review of Literature from 2011 - 2020

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ABSTRACT

The main purpose of this study is to examine existing literature on how inventory performance in the automotive manufacturing supply chain can be improved. Articles reviewed are from the last ten years that is related to automotive manufacturing industry and targeted to inventory performance. Transformational changes are happening in the automotive manufacturing supply chains with ubiquitous technology leading the transformation. Inherently, due to its outsourced manufacturing in dispersed locations globally, communication and coordination would be affected in some form. This results in companies in the automotive manufacturing supply chain resorting to hold more inventory to mitigate the uncertainty. Therefore, to address this issue, this study conceptualises a theoretical framework that is adapted from Galbraith's (1974) Organisational Information Processing Theory. The recommended framework may provide a guide to practitioners on understanding the intricacies of supply chain integration and how technology tools may help in mitigating risks and improve inventory performance.

Keywords: *automotive manufacturing, inventory performance, automotive supply chain, bullwhip effect*

INTRODUCTION

The automotive manufacturing supply chains are complex, complicated, and multi-tiered supply chains that are increasingly globalised, with growing markets and mass customised products. As automotive manufacturing involves complex products, they need a variety of different components, sourced from multitude of suppliers dispersed throughout the world with long supply chains (Lochan, 2020). Generally, an automobile is comprised of roughly 5000 parts and materials supplied by single sources (Thun & Hoenig, 2011). A recent study in Brazil by Vieira, Dias, Santos, Pereira, & Oliveira (2019) state that around 7000 different types of materials are actively supplied by approximately 500 different suppliers dispersed throughout the world to their Braga plant in Brazil.

Transformational changes in the manufacturing technology such as the adoption of IR4.0 concepts is having an impact on the supply chain globally, and it is believed that IR4.0 will radically transform industry, value chains and business models (Kagermann, Helbig, Hellinger & Wahlster, 2013). Resonating with the rapid adoption of technological changes in the manufacturing, the supply chain too is transforming by digitisation of the supply chain operations such as warehouse inventory tracking through RFID tags and tracking of materials supply in the logistics and distribution. When RFID tags are combined with cloud enabled inventory management practices, inventory levels improved and inventory costs are reduced (Ghadge, Kara, Moradlou, & Goswami, 2020). In fact, there is potential increase in operational effectiveness by digitising the supply chain such as, 30% lower costs, 75% fewer lost sales and decrease in inventory of up to 75% while increasing the agility of the supply chain (Alicke, Rexhausen & Seyfert, 2017).

Inventory build-up at the nodes of the supply chain known as the 'bullwhip effect' (BE), is a major problem in the supply chain (Wang & Disney, 2016). It can lead to excessive inventory or shortage throughout the whole supply chain, capacity constraints - excess or shortage, product unavailability, higher total supply chain cost, and loss of revenue (Wang & Disney, 2016). Among some of the reasons that cause the BE are lack of coordination and information sharing among the supply chain partners (Bhattacharya *et al.*, 2011; Tanweer, Li, Duan & Song 2014). The BE is prevalent in the automotive supply chain due to its globalised approach to manufacturing and mass customisation of products with numerous parts and materials suppliers spread throughout the world (Lochan, 2020). With the advancement in computing technology, simulation software are used to analyse real world inventory problems of the automotive supply chains. This could avoid excessive inventory stocking at any node of the supply chain. In a systematic literature review of published case studies that applied simulation in their supply chain networks, Maina & Mwangangi, (2020) state that inventory reduces from 53 days to 10 days, which is a substantial cost savings to the supply chain. Increasingly, number of studies indicate that the BE has not been effectively addressed yet (Goel *et al.*, 2020).

Within the local context, existing studies have suggested that inventory problems can be reduced through a combination of collaborative efforts and technology solutions, even with an inadequate system (Roslin, Razak, Bahrom, & Rahman, 2015). While others in the global context may argue that traditionally, technology solutions such as RFID and ERP systems were used all the time to generate data (Sanders & Swink, 2019).However, these systems are still unable to handle the increasing volume, velocity and variety of the data generated (big data) by various new sources (Balaraj, 2013). Even so, information and communication technology (ICT) is essential to facilitate the exchange of information among supply chain partners for operational benefits, specifically in areas such as reducing transaction costs including transportation, communication, process integration and inventory (Pérez-López *et al.*, 2019).

Academic research on supply chain related operational problems such as inventory management and inventory performance efficiencies in the local context are lacking (Rajagopal *et al.*, 2017; Mohamad, *et al.*, 2019). To date, there are very few studies done to understand the BE or other inventory performance problems in the Malaysian context. With the advent of IR4.0 and SC4.0, proliferation of new technologies and transformational changes are making it inevitable to seek appropriate solutions to be part of a globally competitive supply chain. Therefore, the objective of this paper is to develop a research framework that involves sharing and coordination of information within a firm and with its supply chain partners for inventory performance improvement.

RESEARCH METHOD

A systematic approach to literature search was done to ensure only relevant articles related to the research are included for further review. Google Scholar and OUM-MyVLE (Emerald, Ebsco, and ProQuest) databases were used to search a broad category of relevant articles from journals and publications using keywords. This approach generated approximately 2950 articles. To filter through these articles, advanced search was used to select closely relevant articles related to this research. Article titles, abstracts, and in some cases the introduction sections were scrutinised before including the articles for final selection. The search further included only peer reviewed English journals and publications from the years 2011 to 2020, to ensure that the latest development in the area of research is included. Finally, only 40 papers were found to be very relevant to the research.

Table 1: Inclusion and Exclusion Criteria

Criterion	Inclusion	Exclusion
Literature type	Journals, academic publications, thesis	Books & conference papers
Language	English	Non-English
Period	Between 2011 – 2020	Before 2011
Industry	Automotive manufacturing	Non-manufacturing

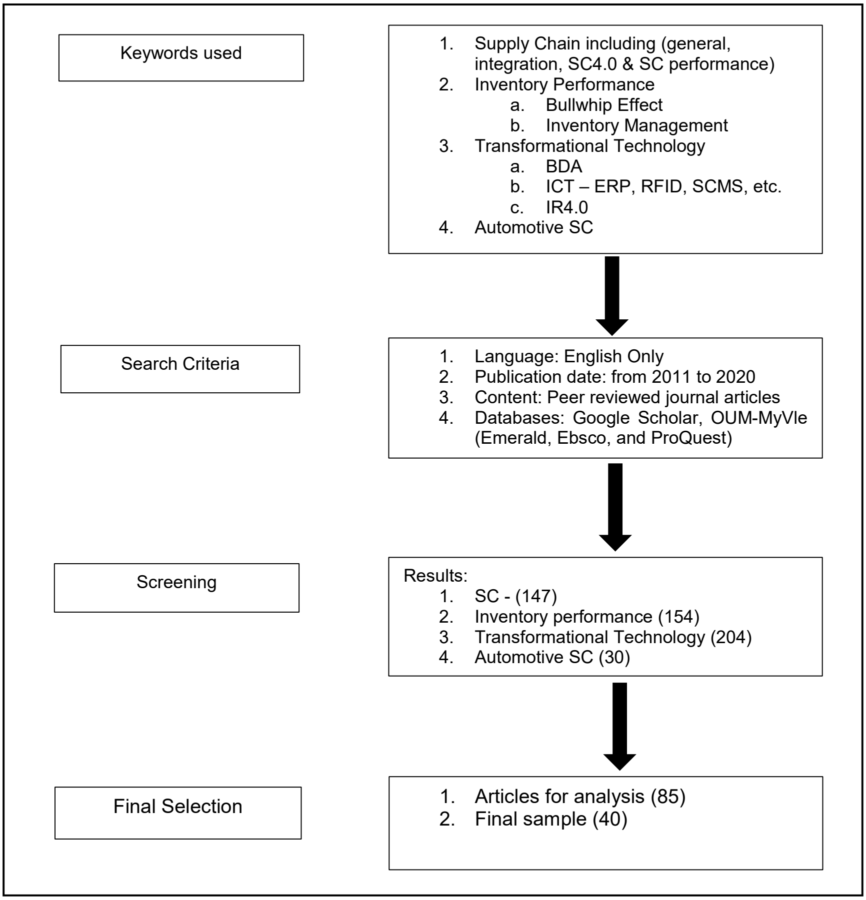

Figure 1: Literature Search Methodology for This Research

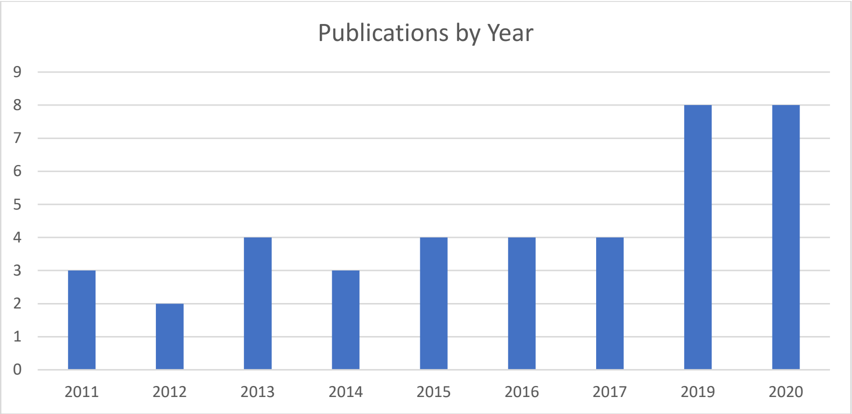

Figure 2: Year-Wise Extraction of Papers

The distribution of publications per year of the selected 40 articles is shown in Figure 2 above. It can be noted that there were consistent extraction of articles from 2011 to 2017 with a peak in 2019 and 2020 indicating that there were more articles available for review during these period and possibly more research papers have been submitted but not reviewed in this research. This shows the importance of research consistently being carried out in this area.

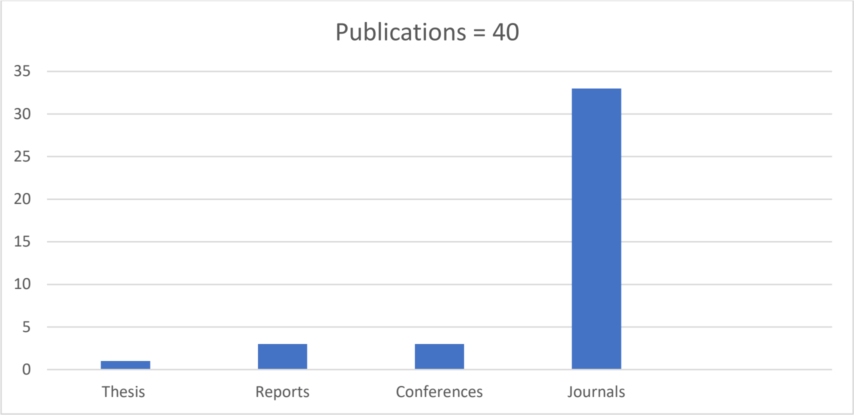

Figure 3: Sources of Publications

Figure 3 shows that most of the research materials were extracted from journal publications while only three papers each from conference and reports were included.

Table 2: Type of Publications and the Number of Papers Being Studied

Type of Publications	No. of Papers
Applied Mathematical Modelling	1
Computers & Industrial Engineering	1
Conferences	3
Decision Sciences	1
Industrial Marketing Management	1
Interfaces	1
International Conference on Social Science Research	1
International Journal of Advanced Manufacturing Technology	1
International Journal of Information Management	1
International Journal of Manufacturing Research	1
International Journal of Operations & Production Management	1
International Journal of Physical Distribution & Logistics Management	1
International Journal of Production Economics	3
International Journal of Production Research	3
Japan Society of Mechanical Engineers	1
Journal of Accounting, Business and Management	1
Journal of Business Logistics	1
Journal of Intelligent Manufacturing	1
Journal of Lean Systems	1
Journal of Logistics Management	1
Journal of Manufacturing Technology Management	1
Journal of Operations Management	1
Journal of Science & Engineering Technology	1
Journal of Supply Chain Management Systems	1
Manufacturing & Service Operations Management	1
Production and Operations Management	2
Reports & Briefings	3
Supply Chain Management Review	1
Sustainability	1
The IUP Journal of Business Strategy	1
Thesis	1
Total	40

Table 2 displays a cross section of journal publications that were extracted for this research reflecting the multidisciplinary approach to inventory problems.

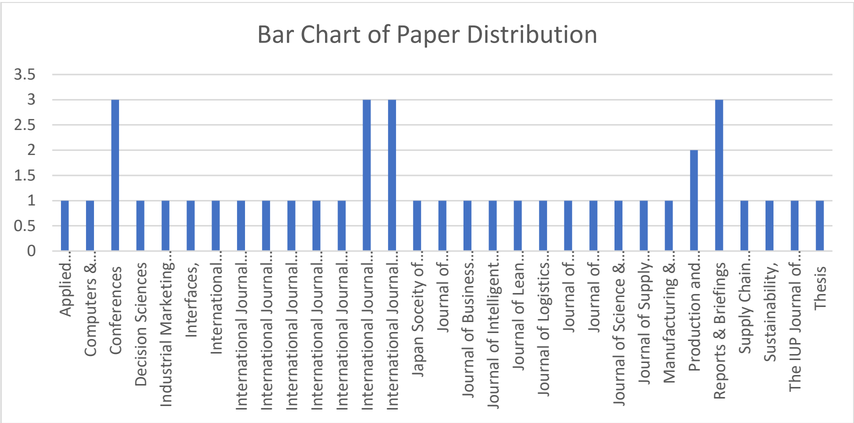

Figure 4: Bar Chart Displaying Journal with Frequency of Papers

Table 3: Categorisation of Research Papers

Category	Definition	Papers
SC Technologies	Includes: BDA, IoT, RFID, ERP, IR4.0,etc.	(Alicke *et al*., 2017), (Balaraj, 2013), (Ghadge *et al*., 2020), (Hofmann, 2017), (Kagermann *et al*., 2013), (Lochan, 2020), (Madapusi & D'Souza, 2012), (Mohamad *et al*., 2019), (Rajagopal *et al*., 2017), (Sanders & Swink, 2019), (Vieira *et al*., 2019), (Wang *et al*., 2016)
SC Management	Includes: operational & strategic	(Balfaqih & Yunus, 2013), (Lambert & Enz, 2016), (Min *et al*., 2019), (Orenstein *et al*., 2016), (Singh *et al*., 2012), (Thun & Hoenig, 2011), (Alvim & Oliveira, 2020), (Han *et al*., 2020), (Maina & Mwangangi, 2020)
Bullwhip Effect	Includes: Causes, mitigation, operational, behavioural, etc.	(Bhattacharya & Bandyopadhyay, 2011), (Bray & Mendelson, 2015), (Li, 2013), (Pastore *et al*., 2019), (Shan *et al*., 2014), (Tanweer *et al*., 2014), (Wiedenmann & Größler, 2019), (Goel *et al*., 2020)

Information Sharing	Includes: integration, sharing of information, etc.	(Jeong & Hong, 2019), (Madhani, 2015), (Peng *et al*., 2014), (Pérez-López *et al*., 2019), (Srinivasan & Swink, 2015), (Stevens & Johnson, 2016), (Vanpoucke *et al*., 2017), (Modi & Mishra, 2011), (Roslin *et al*., 2015), (Vosooghidizaji *et al*., 2020)

Table 3 shows the classification of papers according to categories. Categories indicate the area of concern and are broadly classified with common research theme, example Supply Chain Technologies may involve transformational technologies like Big Data, Cloud-ERP, etc. Supply Chain Management may involve an array of subjects related to supply chain that is related to this research. Similarly, Bullwhip Effect may involve causes, identification, mitigation and cost perspective, while Information Sharing involves integration and collaboration initiatives.

FINDINGS AND DISCUSSION

Literature reviewed on SCM suggest that, at its core, supply chain management is all about increasing customer value and satisfaction, reduce cost and create competitive advantage, through a network of linked upstream and downstream organisations (Lambert & Enz, 2016). While these linked organisations are dependent upon each other, traditionally they do not closely co-operate with each other (Stevens & Johnson, 2016). As such it is challenging to integrate and co-ordinate the flow of materials, the distribution systems, and the management of multiple intermediaries (Stevens & Johnson, 2016). The management of inter-firm relationships is necessary for the success of the supply chain (Lambert & Enz, 2016). However, internal cross-functional collaboration is also essential, without which a firm's capabilities to fulfil its customers' needs and customer lifetime value effectively may be jeopardised (Madhani, 2015). Internal cross-functional collaboration between departments is necessary to avert departments from narrowly concentrating on internal issues such as turf protection and blame-games instead of concentrating on serving customers.

Traditional supply chains tend to interact as disconnected entities receiving sporadic flows of information over time, for example, siloed functional approach in providing information, selectively and as and when needed. Supply chain management (SCM) of the late1990's has evolved and is at a crossroad in the age of IR4.0 and digitised supply chains (SC4.0). Supply chains are now integrated and tend to be customer focused and information flow is continuous. As information sharing is important in supply chain management performance (Balfaqih & Yunus, 2013) it should be linked to external partners of the supply chain to be effective (Singh, Kumar, & Shankar, 2012). A study by Srinivasan and Swink (2015) found that integration and technology investments does produce superior operational performance. Rapid technology development and information sharing capabilities have enabled the sharing of demand information along the supply chain to reduce inventory in many Fortune 500 companies (Min, *et al.*, 2019). Information technology supported supply chain integration does increase operational performance, specifically supplier integration (Vanpoucke, Vereecke, & Muylle, 2017).

Important factors that influence information sharing are cost, supplier-buyer relationship, the degree of integration, system capabilities, and power relationships. A systematic literature review conducted by Vosooghidizaji *et al.* (2020) on how information asymmetry impacts supply chain coordination, found that majority of the papers analysed concentrated on cost or demand information asymmetry. There are also other forms of information asymmetry that needs to be analysed for better supply chain coordination, such as effort level information, disruption information, green degree information, bilateral and multilateral information asymmetry (Vosooghidizaji *et al.*, 2020).

While information sharing in supply chains have been traditionally structured and well-defined like the capture of transactional information, supply chains will have to adapt to evolving needs of new supply chains that are technology enabled (Orenstein, Ladik, & Rainford, 2016). If adequate information is shared frequently (Jeong & Hong, 2019), uncertainty can be reduced and consequently the bullwhip effect (which affects inventory performance) can be mitigated (Hofmann, 2017). The Bullwhip Effect (BE) is quite evident in automotive companies (Bray & Mendelson, 2015; Pastore *et al.*, 2019).

Inventories are essential to fulfil customer needs. Inventory management involves having the right material at the right place to fulfil the needs of the customers immediately. In the process of ensuring the right inventory is available, focal firms need accurate information about consumption patterns and appropriate forecasting tools to plan the acquisition and replenishment of stocks. As the main objective of inventory management is to ensure materials are available when needed, it is also essential that it is made available at an optimal cost to the organisation (Li, 2013). Lean manufacturing practices can reduce inventory holding tremendously by increasing turnover from three to five times to 20 times per month (Alvim & Oliveira, 2020).

However, in fulfilling customer needs companies tend to keep safety stocks as a buffer which by itself is a complex task (Vieira *et al.,* 2019). Usually, the cost is overlooked for the assurance of mitigating risks of no inventory. Uncertainties in inventory management, results in risk averse activities such as adding too much inventory to serve customers. Increasing inventory is an option that organisations have as it increases slack in the process to overcome information processing deficiency, albeit with cost implications (Modi & Mishra, 2011).

A firm level study conducted by Bray and Mendelson, (2012) on U.S. public companies, have shown that 65% of these firms' exhibit BE and it has economically meaningful effects. The mean quarterly standard deviation of upstream orders (supplier related) exceeded that of demand by $20 million. Another study conducted by Shan, Yang, Yang, & Zhang, (2014) on Chinese public firms too found that 67% exhibit the BE. While the BE is not the only way to understand inventory performance, it gives us a broader picture of the general supply chain inventory situation. BE measures the variance of what was forecasted against what was consumed. It also displays economic effects such as storage cost, shortage cost, manufacturing cost and replenishment times (Wiedenmann & Größler, 2019).

Based on the evidence from literature review of this study, the supply chain integration (internal, customer and supplier integration) forms the core requirement for the sharing and coordination of information. While information sharing is fundamental to supply chain efficiency and effectiveness, organisations require basic technology capability such as an ERP system, EDI, etc., to share critical information whether within the firm or between supply chain partners. As technology is rapidly changing the supply chain environment, technology capabilities and tools such as big data analytics (BDA) may influence inventory performance. As such this research framework should also include technology capability and BDA as influencing variables.

In conceptualising the theoretical framework, the Organisational Information Processing Theory (OIPT), (Galbraith 1974, 1977; Peng, Heim & Mallick, 2014; Srinivasan & Swink 2015) was found to be most appropriate in examining how information processing capabilities can improve inventory performance in the automotive manufacturing companies of Malaysia. While the strategies suggested by Galbraith (1974) has its merits based on cost and capabilities of the organisation, however not all strategies are applicable to this research. For example, the OIPT suggests that to reduce the need for information processing organisations can increase slack resources (increase inventory holding) and/or increase self-contained tasks which leads to loss of resource specialisation. Increasing redundancy by holding excess stock may not reduce frequency of disruptive events. Hence, investing into supply chain resilience capabilities and performance measurement may benefit (Han *et al.*, 2020) As this research is to determine how to improve the inventory performance, both these strategies will contradict the purpose of the study. Therefore, as suggested by Galbraith (1974), two other strategies such as investment in vertical information systems and creation of lateral relations are explored. Investment in vertical information systems can increase the organisations capacity to process information, such as using ERP and EDI systems. Though investment in vertical systems as suggested by Galbriath (1974) is relevant, this research extends the vertical systems and adopts modern information processing tools and other supply chain management systems (SCMS) to the study. According to OIPT, the creation of lateral relations involves the formation of teams, matrix structures, dealing with informal groups, and leadership roles. In the current supply chain environment, creation of lateral relations strategy is already incorporated into intra-firm organisational relationship, such as using ERP, MRP and EDI systems that engages in supply chain integration efforts which increases the information processing capacity. Figure 5 below depicts these relationships.

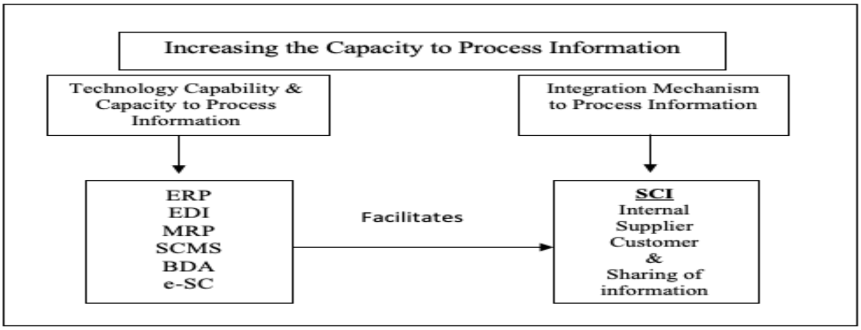

Figure 5: Adaptation of OIPT View to This Research

In the OIPT context, the organisation's options are to reduce the need for information processing or increase the capacity to process information as shown in Figure 5 above. As such, in the absence of technological solutions organisations may resort to reduce the need for information processing by creating slack resources such as holding more inventory (the greater the uncertainty greater the inventory, lead time or budget). This research investigates how inventory performance can be improved; hence, the concern is not creating slack resources as this reduces the need for information processing. Besides, with modern technology tools, processing information cost effectively will mitigate the cost of holding more inventories as slack resources can also be costly (Modi & Mishra, 2011).

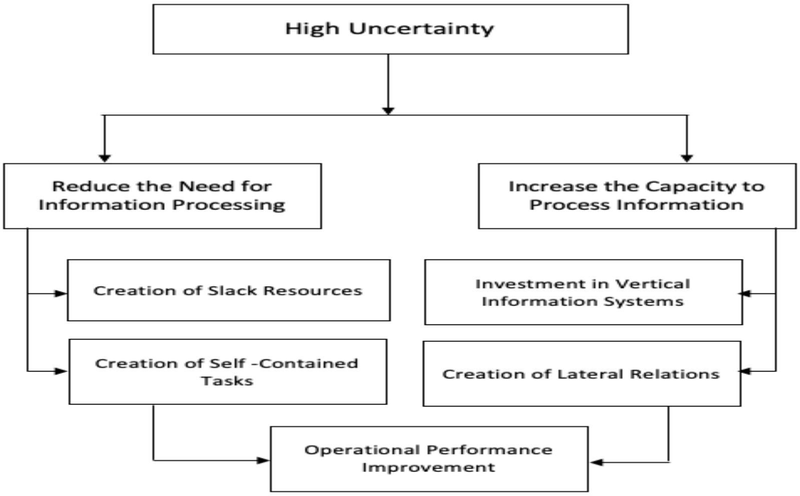

Figure 6: OIPT View of Improving Organisational Performance
Source: Adapted from Galbraith (1974)

Overall, the OIPT by Galbraith, (1974) seem to be the most appropriate theory to investigate inventory performance improvement of a firm and the supply chain. The advantage of this theory over other theories is that the framework is similar, and the variables need very little adaptation. Besides, the OIPT has evolved over the years and the core concepts of uncertainty has not changed but the OIPT has moved towards information systems (IS) based approach as technology is ubiquitous in handling uncertainty (Madapusi & D'Souza, 2012).

Therefore, based on the foregoing findings, this paper suggests the essential constructs that may influence the inventory performance of the Malaysian Automotive Industry as in Figure 6.

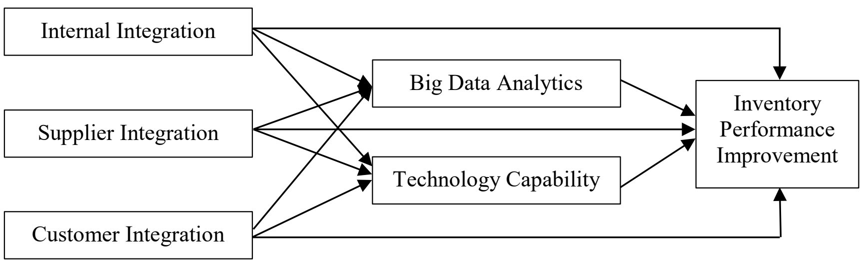

Figure 7: Proposed Research Framework

CONCLUSION

This study provided an overview of the complexities of globalised automotive manufacturing supply chains. The automotive manufacturing supply chains are so complex and dispersed throughout the world that new forms of digitised supply chains (SC4.0) with technology capability and technology tools are necessary to share relevant information and coordinate with supply chain partners to effectively fulfil demanding customer needs. A common problem in the automotive manufacturing supply chain is that inventory tends to build up at the nodes of the supply chain which are necessary to mitigate the uncertainty posed by distance and multitude of suppliers. Hence, this study embarks on determining how inventory performance could be effectively improved through supply chain integration and sharing of information within and with external supply chain partners.

This systematic review is expected to provide academics further evidence on the importance of supply chain integration to the automotive manufacturing industry, even though supply chain integration has been explored extensively in other manufacturing supply chains. The study shows that though information sharing is vital to improve inventory performance, it however, requires modern technology capability and tools to assist in this effort.

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