Implementing DDMRP
Supply Chain Transformation Through Inventory Management

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Abstract
An organization's systematic operation and supply chain management are the criteria for developing a sustainable competitive advantage over other companies. However, fulfilling this goal has become increasingly difficult in today's business environment, as traditional planning and control methods were not designed to withstand such difficulty, hence making the supply chain very complex. This complexity emanated due to high demand and supply variability in the system. In this regard, companies experience a lack of required materials or unavailability of the materials needed for production purposes. Such a situation prompts the movement of planners migrating from the traditional deterministic domain, Push-based MRP methodology to a more systematic pull-based demand-driven material requirement planning (DDMRP) approach that works in a more complex and unstable business environment, with an unparalleled characteristic for maintaining flow stability in the manufacturing operation.

The establishment of DDMRP is for the sole purpose of maintaining a proper flow with the main intent of inventory monitoring as well as the associated cost. This proposition suggests the identification of specific items at strategic positions for planning maintenance flow in the production process. It basically centers on regular monitoring of the inventory buffer level sufficient enough to sustain the flow in order to avoid any operational disruption.

The Insufficient understanding of the DDMRP methodology makes the practitioners unable to implement the concept in a proper manner, thereby not achieving the proposed result. This research, however, investigates the subject of DDMRP as a more efficient planning and execution strategy for proper flow management affecting the overall dynamics of supply chain management.
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<td>ADU</td>
<td>Average daily Usage</td>
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<tr>
<td>APS</td>
<td>Advanced Planning and scheduling</td>
</tr>
<tr>
<td>ASRLT</td>
<td>Actively synchronized replenishment Leadtime</td>
</tr>
<tr>
<td>BOM</td>
<td>Bill of material</td>
</tr>
<tr>
<td>CLT</td>
<td>Cumulative lead time</td>
</tr>
<tr>
<td>CSF</td>
<td>Critical success Factors</td>
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<tr>
<td>DLT</td>
<td>Delivery Lead time</td>
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<td>DDMRP</td>
<td>Demand driven material requirement planning.</td>
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<td>ERP</td>
<td>Enterprise resource planning</td>
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<td>IO Map</td>
<td>Intermediate objective map</td>
</tr>
<tr>
<td>JIT</td>
<td>Just -In-time</td>
</tr>
<tr>
<td>MLT</td>
<td>Manufacturing lead time</td>
</tr>
<tr>
<td>MOQ</td>
<td>Minimum order quantity</td>
</tr>
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<td>MPC</td>
<td>Manufacturing planning and control</td>
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<td>MRP</td>
<td>Material requirement planning</td>
</tr>
<tr>
<td>MRPII</td>
<td>Manufacturing resource planning</td>
</tr>
<tr>
<td>NFP</td>
<td>Net flow position</td>
</tr>
<tr>
<td>OMAX</td>
<td>Over Maximum</td>
</tr>
<tr>
<td>OTOG</td>
<td>Over the top of green</td>
</tr>
<tr>
<td>OUT</td>
<td>Stockout</td>
</tr>
<tr>
<td>ROI</td>
<td>Return of Investment</td>
</tr>
<tr>
<td>TOC</td>
<td>Theory of constraint</td>
</tr>
<tr>
<td>TOR</td>
<td>Top of red</td>
</tr>
<tr>
<td>TOY</td>
<td>Top of yellow</td>
</tr>
<tr>
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1. Introduction

The purpose of this chapter is to present the theoretical background on which the foundation of this project is built. It is followed by a description of the problem, purpose of the research, and research question. There is then a discussion of some of the study’s limitations.

1.1 Theoretical Background

Supply chain can be defined as a set of value-adding activities in a manufacturing organization that links the suppliers and their respective customers (Sukati et al., 2012). The idea behind a supply chain is simply adding values from the received input from the company’s supplier, which is then passed on or delivered to the expected customer. According to Thoo et al. (2017), the supply chain emanates from the imputed endeavors and ability of the manufacturing company to produce and deliver finished goods and products from the suppliers to the customers. Inputted efforts range from all processes that consist of planning, sourcing which is confined to matching supply with demand, sourcing constituents, and raw materials in order to produce the final product, delivering it to the end user, and offering post-manufacturing services like returns, repairs, and warranties.

The supply chain within the manufacturing company has become increasingly complex over the past decade, making it more difficult for manufacturing firms to plan and manage their resources (Ptak and Smith, 2011). Thus, globalization, sustainability, customization, innovation, and flexibility contribute to increased supply chain complexity (Serdarasan, 2013). According to Ptak and Smith (2011), this complexity has become an increasing concern for manufacturing companies as several surveys have suggested the need for supply chain enhancement within manufacturing companies. Furthermore, the triggered complexity resulted in high demand variability and supply variability. As a result, such fluctuations give a distorted and inaccurate picture of demand-supply status, causing nervousness in the entire system, and ultimately affecting production flow, thereby causing chaos in the system (Gopal and Seth, 2021). Hence, a company’s supply chain must be well-planned and executed to thrive in the complex market.

Bugert and Lasch (2018) reiterated that a well-structured supply chain strengthens the company’s competitive edge in meeting customer requirements and satisfaction. Furthermore, one of the ways to enhance competitive advantages through supply chain management is by implementing proper inventory management. Moreover, the supply chain can be systematically managed by simultaneously planning and controlling inventories and activities. Inventory management is the part of the supply chain that refers to the inventory’s planning, organizing, handling, and monitoring. It ensures maintaining the equilibrium between demand and supply while minimizing the investment in inventory. The process undoubtedly entails the management of supply, storage, and availability of materials in order to guarantee a sufficient supply without uncontrolled oversupply (Singh and Verma, 2018).

However, manufacturing organizations face unprecedented disruptions within their supply chains because of high variability on the supply and demand end due to the difficulty, which emanated from globalization, ultimately affecting the inventory situations and positions either by the lack of required materials for production or the excess availability of unwanted material. At this point, inventory behavior is said to be bimodal in nature (Gopal and Seth, 2021). Ptak and Smith (2011) further stated that bimodal inventory behavior indicates the level of inventory complexity within the supply chain due to a certain level of demand-supply variability. As a result, inventories in almost every organization tend to experience shock problems, either due to a lack of material needed for production or severe cost impact on the company due to dead capital built-up from unwanted inventory. Moreover, several recent complications have arisen due to the increasing complexity emanating from the global manufacturing and supply landscape. One such difficulty includes the misalignment of supply order generation to the actual demand due to the constant...
information mismatch between the manufacturer and supplier. This misalignment paved the way for the bullwhip effect situation in the system, which ultimately triggered poor inventory performance, poor service level, and increased cost (Ptak and Smith, 2011). Due to these complications and complexity, it became expedient for manufacturing organizations to re-examine the conventional planning system to maintain a smooth operational flow (Ptak and Smith, 2011).

DDMRP was established in 2011 and can be defined as a formal multi-echelon planning and execution method that creates and manages strategically placed decoupling point stock buffers to protect and promote information flow. DDMRP was developed as an innovative approach to planning and execution to control any manufacturing firm’s supply chain. DDMRP achieves its purpose by managing the inventory level and related costs by focusing on the flow of operations. Through DDMRP, the supply chain can be transformed from push to pull, eliminating the influence of the bi-modal effect. This primary procedure involves constantly observing the inventory buffer levels to guarantee they are suitable for a proper and uninterrupted flow. DDMRP, regarded as an innovative planning and execution method, was developed to address these complications within the supply chain. This was initiated because the traditional MRP planning system, which was the standard planning methodology before the advent of DDMRP, could not cope with such variability of demand and supply in an increasingly complex manufacturing environment. In addition, MRP planning was associated with flaws, such as inflexibility in production scheduling and high implementation costs. With such drawbacks, DDMRP was introduced to absorb these flaws and maintain smooth operational flow by countering demand and supply variability, justifying the need to initiate a production plan to effectively sustain the supply chain through a proper inventory management system. (Ptak and Smith, 2011)

1.2 Problem Description

Demand and supply variabilities can be triggered by factors and circumstances related to the uncertainty of demand and supply and complexity due to globalization, which could further result in delays in materials delivery and operational challenges. In addition, these variabilities erupt due to the unstable nature of the modern-day manufacturing business, prompting further demand uncertainty aside from improper forecast. This factor creates more distortion on the supply chain by affecting the inventory either by the scarcity of raw materials for production or by accumulating undesirable inventory in warehouses, which could ultimately affect the cost through capital tied up. The resulting imbalance in inventory due to high demand and supply variabilities can be referred to as bimodal inventory behavior. And this is said to be a major constraint in the present-day manufacturing environment. (Gopal and Seth, 2021)

Furthermore, the supply can be affected due to unplanned and unanticipated events, which could further disrupt the normal flow of goods and raw materials for production purposes (Macdonald and Corsi, 2013). Such a situation is known as a supply chain disruption. One such distinct example is the bullwhip effect, a significant drawback for manufacturing industries. The bullwhip effect within the supply chain is a persistent problem because of the misalignment of supply order generation as materials move from upstream to downstream due to the complexity of the global manufacturing and supply landscape (Ptak and Smith, 2011). This effect has a negative impact on inventory, customer delivery lead time, and cost of operation. An improper forecast can also factor into the misalignment of supply orders, resulting in inaccurate stock levels and excess inventory, ultimately wasting resources when there is low demand, leading to poor inventory management and improper production planning. Because of this, companies lose money, time, and effort when they attempt to fulfill customer orders. Whenever the company tries to complete a customer order, it loses money, time, and effort due to the lack of inventory management and production planning. In terms of financial losses, manufacturing companies suffer from dead capital buildup that could have been used to increase profit for the company and so on. In terms of time and effort,
the company wastes resources on non-value-added activities such as finding the right size of material in the required quantity from the unused material pile during the start of its production processes. It was further observed that firms implementing MRP planning systems face limitations as the traditional MRP planning systems do not function in such a volatile environment but work best in an environment of stable demand and supply (Shofa and Widyarto, 2017). Therefore, it is imperative to tackle this variability by developing a new innovative solution to counteract these challenges in inventory management and supply chain modalities in manufacturing planning perplexity, service level, and customer order lead time. Hence, the emergence of DDMRP as an innovative planning model addresses and tackles these complications at the inventory management and supply chain levels.

1.3 Purpose and Research Question
Based on the problem stated, this research aims to explain how the DDMRP approach can be used as an adaptive planning tool to act against supply chain disruptions by tackling demand and supply variabilities to counter the unusual inventory behavior and also to counteract the bullwhip effect within the supply chain in the manufacturing sector through inventory management. This will be done by systematically reviewing and analyzing the literature on DDMRP as an innovative planning methodology concerning inventory and supply chain management.

The aim of this research will be achieved by providing the necessary answers to the following research questions.

RQ 1. What is DDMRP and its components?
RQ 2. How can DDMRP handles supply chain disruption?
RQ 3. How can DDMRP handles demand and supply variabilities?
RQ 4. What are the challenges and opportunities with DDMRP applications in the manufacturing Industries?

1.4 Delimitations
This research study investigates the concept of DDMRP and its implementation to transform the supply chain through inventory management. Moreover, like every other research, this study is constrained by boundaries. In this research, DDMRP will be associated with the improved MRP system in conjunction with supply chain management; other planning methodologies will not be considered. Also, the scope of this study will be restricted solely to manufacturing organizations and industries. Furthermore, this research neglects any company-specific issues on DDMRP and supply chain implementation, but only studies and literature based on the subject matter will be considered.
2. Methods and Methodology

The numerous approaches utilized at various phases to arrive at solutions to research questions are described in this chapter of the thesis. The outcome of this study also depends on the methodology employed, the caliber of the content in terms of information quantity, the reliability of the results, and the legitimacy of the information used. This chapter offers perceptions into the sources from which the various information included in this thesis was selected, as well as how all the data, materials, and information were combined to enhance comprehension of the concepts and framework.

2.1 Qualitative and Quantitative Studies

Qualitative research is a reflexive approach commonly described as a naturalistic, interpretative approach that begins with the views and accounts of participants and continues through the research process (Ormston et al., 2014). The sole purpose of qualitative research is to facilitate participants with an in-depth and interpreted understanding of the research subject by building facts around circumstances, experiences, perspectives, and histories (Ormston et al., 2014). Qualitative research is further characterized by utilizing a unique, flexible method of information gathering which is responsive to the social content of the study and can be modified for researchers for future investigations. Qualitative research offers understanding and insights into the problem settings. Through observation and interpretation, a qualitative approach can be utilized to learn how people feel and think by understanding their behavior, experiences, attitudes, intentions, and motivations (Ahmad et al., 2019).

Case studies, ethnography, historical research, grounded theory, and phenomenology are a few examples of qualitative research types. On the other hand, a quantitative study is a type of research that utilizes the techniques used in the natural sciences and yields complex data and numbers. It uses mathematical, computational, and statistical methods to establish a causal connection between two variables. (Ahmad et al., 2019)

Considering the idea of DDMRP being utilized as an approach to supply chain transformation via inventory management concerning the customer’s demand and supply, this research will be conducted using a qualitative method. Hence, the content of this study will be framed under the characteristics of qualitative research since the required information gathered for analysis will be obtained through a substantial literature search that will be well grounded, with detailed information and explanation of processes in an identifiable local context. Although a qualitative approach is a theory used in this study, it is also necessary to note that the information provided will be gathered from various studies on DDMRP by several authors who peradventure must have analyzed DDMRP studies either through qualitative or quantitative regards.

Furthermore, Bryman (2016) illustrated the procedural pathway qualitative research should follow to achieve its aim and objective, giving the reader a clear and distinctive view. The Figure1 below describes Bryman’s approach to performing qualitative research. In order to perform this research, the research aim and questions were first mapped out based on the analysis of section 1.3. Information was then collected from online sources and selected to perform this research. In the following step, the information was collected from the sources selected in the previous stage to build up a theoretical framework. Next, an analysis of this information will be carried out in an attempt to provide answers to the research question. This was done by analyzing materials related to DDMRP and inventory management in the manufacturing industry by considering the information collected from various researchers. The analyses were further enhanced by citing more literature of similar interest to validate the findings. Finally, a summary of the findings will be drafted. Afterward, the conclusion and recommendation will be presented.
2.2 Positivism and Interpretivism

An appropriate perspective must be determined based on the type of study and its context. Positivism and interpretivism are the two essential points of view used (Thanh and Thanh, 2015). In positivism, research focuses on discovering significant and quantifiable facts or regularities, and the research findings should ultimately lead to a sense of credibility and relevance in the information collected. Furthermore, the research purpose under this category is to determine the informal interconnections to create law-life generalization similar to scientific findings further. Positivism generally considers the significance of what is being presented, with a stricter focus on considering credible information and facts without being impacted by interpretation or human prejudice (Scotland, 2012; Saunders et al., 2012). It uses fundamental universal principles and laws to support and explain the observed behavior or occurrence within organizations. According to epistemology, the inquiry also finds observable and quantifiable facts or regularities (Alharahsheh and Pius, 2020). Contrary to positivism, interpretivism is more concerned with in-depth variables and elements. It views people as distinct from physical phenomena because they provide greater depth on the presumption that people cannot be thoroughly examined (Scotland, 2012).

The perspective of research is essential for its success and depends on the research's nature and content and how the information will be collected. Positivism centered on technical and scientific viewpoints in connection with credible information. At the same time, the adoption of interpretivism, on the other hand, is more connected and centered on the comprehension of a certain context with the influence of development through the gathering and translating qualitative data (Alharahsheh and Pius, 2020). Hence this study considers positivism because of its ideology to be applied to this research, as the research will adhere to the view based on factual knowledge gained through scientific discoveries. More so, the research is constricted to information gathered from previous research on DDMRP. Therefore, positivism is regarded as the best option for this research because it compares variables and parameters between literature from different authors concerning DDMRP.
in a regular agreement pattern and discrepancies across diverse data sources. This is so because the study relies exclusively on literature research.

2.3 Descriptive and Normative Research
Descriptive research can be referred to as a methodology utilized to identify existing phenomena as accurately as possible. Atmowardoyo (2018), stated that “existing phenomena” differentiate descriptive research from experiment research, as the latter examines the existing phenomena and includes the phenomena over a particular duration of treatment. Data is collected in the descriptive study from research instruments, including tests, questionnaires, interviews, or even observation of the events. The purpose of descriptive research is to key out systematically the existing phenomena under the study (Lane, 2011). Alternatively, normative research can be defined as research methods that search to discover and enlighten people about what they should do, similar to a set of values such as ethical, legal, religious, and cultural values. Normative research makes arguments with the foundation in value commitments, supported by empirical proof, and appraises in terms of their coherence, quality, scope, and suitability with other value commitments and empirical data (Parker et al., 2019).

It is important to note that this research is drawn from an existing occurrence known as DDMRP, an innovative planning, and execution methodology to smoothen the flow of operations and reduce and possibly eliminate the disruption within the supply chain. Therefore, this research can be described as descriptive because observations and conclusions were drawn from the perspective of different authors and from different scenarios regarding the DDMRP practices and application, which serves the purposes for further description. However, this research cannot be considered normative because of its inability to provide specific guidelines that guarantee the successful implementation of DDMRP. Moreso, this study only provides a base for further research in the future by providing a general viewpoint concerning DDMRP implementation.

2.4 Method of Collecting Information
Research literature reviews are essential in academic research, which revolves around knowledge advancement built on existing works. This method involves developing new theories and testing specific hypotheses by analyzing, summarizing, and synthesizing a group of related works of literature. A literature review is vital to research as it gives a broader perspective on the research's path. The significant importance of the literature review allows for knowledge gain in the chosen area of academic study within the boundaries and limitations of the study. One crucial relevance of reviewing the relevant literature is that it creates the foundation of proper understanding concerning the dimensions of our academic research. The evaluation of this literature can contribute to validating ideas and creating new ideologies. Hence, the strength and characteristics of a proper review should rely on its validity, reliability, and repeatability. (Xiao and Watson, 2019)

A literature review is conducted for the intent of better understanding the topic holistically and proving that the collected information will be helpful in the dissemination of the research findings. The literature review can be subdivided into three classes, and they are integrated, systematic, and semi-systematic review. Firstly, the integrative review methodology aims to examine, analyze, and incorporate the literature on the research, by so doing, creating more room for new viewpoints and theoretical frameworks. Conversely, a semi-systematic review examines the evolution of research on a particular topic. An emphasis was placed on qualitative information rather than quantitative information in this review. And lastly, the Systematic literature review (SLR) methodology requires the researcher to search and access all necessary literature and analyze the information related to the research topic. Furthermore, it is imperative in this case to find all verifiable information that answers specific research questions or ideas and fulfills all necessary criteria. (Snyder, 2019)
Therefore, this research will adopt a review under the Systematic literature methodology to conduct a proper and quality review. Hence this study is practically based on literature gathered from credible sources to buttress the point of the topic and its research questions. Furthermore, Xiao and Watson (2019), stated that comparing different sources helps to do cogent analysis. This would help establish an in-depth understanding of the researcher and the reader. Also, the thorough acquisition of knowledge gathered from different sources serves as a precondition for undertaking substantive, deep, sophisticated research (Xiao and Watson, 2019).

The literature search was conducted using methods highlighted by Xiao and Watson (2019). Their steps include formulating the problem, then developing a review protocol, after which the literature search is conducted and obtained literature is screened using the pre-set inclusion criteria before extracting data and performing analysis. In line with these steps, the review protocols were set to enhance the reliability of the literature review process. The literature search was then conducted using keywords, and each piece of literature obtained during this study was screened using the inclusion criteria to determine its relevance to the study. The data extracted from the relevant literature became the foundation of the analysis phase.

2.4.1 Search Strategy

In order to gather all the required and necessary information for this project, the university library served as the primary source of information. The library contained an extensive amount of the relevant published materials required for this study which was gathered via scientific database tools. Sources such as Diva, books 24/7, and E-book central were the main sources used through this means. Multiple articles were sourced from various backgrounds without constraints to gain a broad comprehension of this research and find relevant literature. Academic databases, including Uni search, Diva, Google scholar, and Scopus, as well as books from the Linkoping university library, were mostly used to locate research articles. First, an extensive search is conducted and then focused on the relevant article. Next, the researcher chooses the publications by first reading through their topics, abstracts, and ending chapters. With this, a choice is made on whether the entire article will be read. The researcher chooses the publications by reading through their topics, abstracts, and ending chapters first. With this, a choice is made on whether the entire article will be read. The choice of an article for this study is based on how well it fits the study's objectives by outlining the concept of DDMRP and how it enhances the supply chain through inventory management.

The need for gathering relevant and precise information regarding the development of this study cannot be overemphasized. A well-structured method is required for this, as it facilitates the research study with the exact conclusion and recommendations for future implementation. It also enhances the research with relevant answers to the provided research questions. To achieve this purpose effectively, specific words about the project topics were used at first to search for relevant information based on a structured pattern that involves searching for relevant information using specific tools as shown in Table 1 below.

<table>
<thead>
<tr>
<th>Table 1: A list of selected keywords used to form the theoretical framework for this study.</th>
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<tbody>
<tr>
<td>Supply chain enhancement through DDMRP</td>
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<tr>
<td>Demand and supply variability</td>
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<tr>
<td>DDMRP Components and Innovative Features</td>
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<tr>
<td>Decoupling points and buffers</td>
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<tr>
<td>Supply chain disruption</td>
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<tr>
<td>Inventory management Policies</td>
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The search started using google scholar using the keywords "Demand-driven material requirement Planning " and "Supply chain enhancement through DDMRP " The first 30 pages of search results were then reviewed, after which 25 potentially relevant articles were identified. A search was then
conducted on a science website utilizing the keywords "Inventory management Policies" and "Supply chain disruption," which yielded about 850 studies. The Initial screening of the titles was carried out, after which 65 potential studies were identified. A search on the Diva portal platform was conducted using the keywords "Decoupling point and buffer" and "demand and supply variabilities" a total of 5 records related to the subject were found after the initial screening. After an extensive search using the different databases, a total of 95 potential studies were identified from the three sources, including six duplicates that could not be included, and based on the title and abstracts, each article seemed relevant to the study. Furthermore, the literature source was then reviewed by reading through the abstract to further decide on the relevancy of the research topic. The idea behind this review is to screen for inclusion. Thereafter, the quality and eligibility assessment of the studies was evaluated by skimming through the full text of the relevant articles. Only articles written in English, published in different academic journals between 2010 and 2023 which contain information on DDRMP and its relevance or application for enhancing supply chain in manufacturing were selected aside from a classic of 2007 which was adopted because of its rich content. Next duplicates and articles which do not meet the inclusion criteria were also removed leaving a total of 90 articles to be reviewed.

- **Inclusion Criteria**
  Peer reviewed articles written in English, published in academic journals between 2010 and 2023. Include only papers that contain information on DDMRP, its application in supply chain enhancement and inventory management.

- **Exclusion Criteria**
  Duplicates and papers that do not contain any of the keywords used in the search was excluded from the study.

2.4.2 Data Extraction

This is an essential process when conducting a systematic review because extracting the wrong information will lead to wrong conclusions at the end of the study. Data extraction involves obtaining relevant information from selected literature to provide answers to each research question. This study adopted a meta-summary approach in which each article was categorized using different codes such that information obtained can be interpreted easily through data frequency and theoretical proposition. Information obtained from each article was analyzed to answer each research question explicitly, and this information was recorded in a clear and easy-to-understand manner.

It is essential to mention that the author observed some notable points while reading the selected pieces of literature. These points were noted with the view of their possibility to provide the needed answers to the research question, which were used in the analysis section of this research. All Research questions were answered in the analysis section of this research by citing and contrasting the various viewpoints from the various piece of selected literature which is in line with the theoretical framework postulated by the authors of DDMRP.

2.5 Method of Analyzing Gathered Information

The analysis of gathered information will be examined from a theoretical proposition strategy, citing the observation from different authors of DDMRP. This will be conducted at different stages to answer the provided research question by describing and building explanations around the deduced information. Below are descriptions of each stage.

2.5.1 DDMRP and components explained

The first section of this analysis will be focused on information regarding the hypothesis behind DDMRP. These fundamentals were built from existing literature to inform the reader about the theories supporting DDMRP and its associated components. This helps to throw more light on the philosophy and supported arguments for establishing the theory behind DDMRP and its application
in the manufacturing industry. The section will also highlight the essence and feature of DDMRPs and their relevance to inventory management, justifying and validating their superiority over traditional planning methods. Furthermore, this section will identify and highlight the critical components of DDMRP in connection to inventory control and the supply chain process. Hence by laying a foundation of knowledge and information, this stage made it possible for the reader to comprehend the primary goal of DDMRP and its overall performance in supply chain management.

2.5.2 The effect of DDMRP on supply chain and inventory
The study then focuses on investigations conducted to ascertain the effects of DDMRP on the supply chain in an organization after defining DDMRP and exploring its implications. The section examines studies that support the notion that DDMRP facilitates inventory transformation and supply chain responsiveness. This will be conducted further in two ways in this regard. First, the study will determine how DDMRP can handle supply chain disruption and counter the effect posed by these disruptions. The section further emphasized how DDMRP can salvage the challenges of demand and supply variability. Variabilities like these are regarded as a setback to the overall planning philosophy.

2.5.3 Challenges and opportunities associated with DDMRP
The last aspect of the analysis is to explore the challenges associated with DDMRP implementation and the opportunities it presents to the manufacturing industry. This will be done in such a way as to illustrate, with some specific examples, from various manufacturing organizations that have practiced and implemented the DDMRP methodology, and the challenges encountered while doing so. Finally, the section will further explain the future expectations of DDMRP implementation to become a standard planning and execution approach for manufacturing companies.

2.5.4 Conclusion
The final phase of the analysis concentrated on comparing the theoretical explanations, DDMRP-related expectations, and the result, as highlighted in various case studies regarding DDMRP implementation. First, the section will entail a detailed discussion in overview as to how DDMRP will be viewed regarding transforming the supply chain dynamics through enhancing the inventory performance. The section will also elaborate on how the research question was answered, with a brief description of the provided result, hence fulfilling the purpose of this research overall, thus giving credence to the validity and reliability of the information gathered. Furthermore, Figure 2 illustrates how the conclusion was drawn from the literature’s analysis, specifically, findings obtained from several works by different scholars on DDMRP. The researcher will obtain these recommendations from various viewpoints while providing the needed answers to the different research questions covered in Figure 2, by which the various scholars of DDMRP arrive at similar perspectives, hence validating answers to these research questions.
Finally, it is essential to mention that information analysis done in this order is vital and peculiar to this research study, as it presents a clearer picture and a detailed understanding of the research topic to the reader. This method also offers a detailed explanation of the research study by citing works of literature by various authors of DDMRP which further strengthens and validates the findings of this research and also helps in outlining a decent conclusion and recommendation for further works. With this, the reader would easily understand the complete concept behind DDMRP, as the method attempts to provide the necessary answers to all the related research questions and more, such as presenting further the advantages of utilizing the DDMRP method.

2.6 Reliability and Validity

Reliability is defined as the degree to which a test procedure produces similar result under constant condition on all occasion, basically repeatability; the main aim for this procedure is to minimize errors. Reliability is an approach used for analyzing quantitative research; the concept of testing in qualitative research is viewed as a way of information citation and making the research quality. Reliability is considered by as the direction of answering in a quantitative approach and developing understanding in a qualitative approach to research. (Price et al., 2015)

Validity on the other hand is a measure to determine the authenticity of a solution provided by research and can be classified as either internal or external validity. A validity of a research is usually determined by the researcher by deducting facts, results and conclusions from other research; hence the study of past literature helps to address the problem of validity and reliability. Validity enhance the credibility and trustworthiness resulting to the generalizability which is a core concept of a high quality qualitative research. (Price et al., 2015)
Therefore, to strengthen the validity and reliability of this research, this study will entail different case scenarios, analyses, and theories to gather the necessary and required information concerning DDMRP application with different firms and the result after implementation of DDMRP and how its application increase business profitability and reduces cost.

2.7 Ethical Considerations
Ethical conflict is unlikely to arise in the study as the study primarily relies on secondary information collected from different sources. However, this study will be conducted in an extremely cautious manner in order to avoid falsification and misinterpretation of the information obtained. Each source will also have proper citations so that the reader can validate whatever is written during the review.
3. Frame of Reference

This chapter outlines the theoretical framework required for conducting this study. In order to achieve the purpose of this research, certain hypothetical domains are considered necessary. As illustrated in the below diagram, the frame of reference is connected to the presented research questions and shown in Figure 3 below. The frame of reference begins with the preliminary information related to the case study DDMRP, as explained in the chapter. To answer RQ 1, an overview of the various theories which form the basic structure of DDMRP is required, as presented in chapters 3.1, 3.2, 3.3, 3.4, and 3.7. The related topics under this category help better understand specific strategies, goals, and obstacles within production planning to emphatically frame up the understanding of DDMRP as an active model to supply chain transformation. Furthermore, the theories presented in chapters 3.5 and 3.6 gives the comprehensive structure needed to answer research questions 3 and 4, as the primary research aim is to conclude findings from these theories. Examples are the bullwhip effect, inventory management, and their amendment to DDMRP implementation. No new theory is necessary to answer RQ4.

Figure 3: Relationship between the frame of reference and research question
3.1 Manufacturing Planning and Control

The manufacturing planning and control (MPC) system is related to outlining and managing manufacturing processes, including man, material, and machine. The MPC methodology addresses resource allocation ensuring individual customers' demands are satisfied over a specified period. Therefore, the development of an efficient and effective manufacturing planning and control system is vital to the success of any manufacturing organization. Furthermore, the MPC system tends to provide the support for decision managers to manage efficiently the flow of material, efficient use of people and equipment, and respond to customer's demand. (Jacobs et al., 2011)

According to Slack et al. (2010), the MPC system activities are made up of three terms; long-term, medium-term, and short-term. The long-term planning and forecast decision on the system responsible for giving out information to make a decision on equipment, buildings, suppliers, etc., to meet market demands is vital as the parameters set from this decision-making helps firm meet their current demand and copes with short-term change in customer choices. This also includes sustaining the proper levels of raw material, work in process, and finished goods inventories in suitable locations to meet market needs (Jacobs et al., 2011). In medium-term planning, the MPC system addresses supply and demand in terms of volume and product mix by providing the exact material and production capacity needed to meet customer needs. In this time frame, the MPC system tends to achieve the objectives of specific coordinated plans, which include corporate budgets, sales plans and quotas, and output objectives (Slack et al., 2010). Short-term planning and detailed scheduling of resources are needed to meet production requirements daily. The MPC system must keep abreast of the use of resources, and process results to report on material demand, labor activities, equipment usage, completion of customer orders, and other necessary measures of manufacturing performance (Jacobs et al., 2011).

3.1.1 MPC Framework

Coordinating MPC system activities involves linking customer and supplier firms in a supply chain; the Figure 4 below illustrates a framework for an MPC system that would be used within a firm for planning and controlling its manufacturing operations.

![Figure 4: Manufacturing Planning and Control System (Adopted from Jacobs et al., 2011)](image-url)
The front end describes the activities and systems involved in setting the overall direction. A manufacturing planning and control system are established during this phase. Demand management manages all activities of the business that place demands on manufacturing capacity involving projecting customer demand, order entry, and promising, accommodating interplant and intercompany demand, it provides the gathered information about the customer needs to the sales and operation and the master production schedule (MPS). The balancing of marketing plans with the necessary production resources is the sales and operations planning. Jacobs et al. (2011) stated that sales and operation planning in progressive firms is getting more management attention as the need for coordination arises. The master production schedule (MPS) tends to forecast which items or product options manufacturing products to develop and control. It uses the information to know product-specific manufacturing plans whenever the customer’s actual demand information is available. Resource planning specifies the ground for manufacturing plans and capacity; it also ascertains the production capacity to produce the required products now and subsequently (Kempf et al., 2011).

A detailed material and capacity planning system is represented by the middle or "engine" phase, as shown in the Figure 4 above. Information obtained in this phase is derived directly from the master production schedule. The master production schedule supplies detailed material planning in the engine region, and companies can specify production rates for developing products with a limited range. However, when producing various products, detailed material planning uses a formal logic called material requirements planning (MRP) in calculating requirements for thousands of parts and components. MRP specify the time-phased plans for components and raw material needed to develop all the products in the MPS. (Jacobs et al., 2011)

The bottom section of Figure 4 represents the back end, which consists of the MPC execution systems, the products manufactured, and the production processes used to determine the system configuration. For orders to be scheduled appropriately, the shop floor system initiates priorities for all shop orders at each work center. Information on the firm's suppliers is detailed on the supplier system as it develops purchase orders that will be communicated to the suppliers. A detailed MPS drives the back end. MRP requires the bill of materials and inventory status as two primary inputs along with MPS. MRP plays a vital role in producing and assembling end products from components. It helps in detailed material requirement planning as it takes in a time-phased master production schedule requirement and develops time-phased components. (Jacobs et al., 2011)

As per Ptak and Smith (2011), MPC has to do with the planned order for the production process concerning the flow of raw materials through the plant to the individual customers in connection with information flow. Ptak and Smith (2011) further elaborated on the necessity of an effective planning in manufacturing operations; an effective planning system facilitates a proper production flow by reducing bottlenecks and aiding a proper control process. With such, managers and decision-makers can make either long or short-term decisions without any difficulty. Moreover, the Inventory levels can be effectively managed since the production and delivery delays tend to be reduced with a proper MPC system.
3.2 Material requirement planning

Material Requirement Planning (MRP) can be referred to as a set of methodology that uses Bill of Material (BOM) data, data collated from inventory, and Master Production Schedule (MPS) to determine requirements for material. It helps to accomplish replenishment orders for material. Reorder point systems were used by various firms before converting to MRP during the mid-1960s; the change helped to minimize inventory holding costs, customer service improvement, and operational costs (Ptak and Smith, 2011). According to Kortabarria et al. (2018), MRP is a substantial tool for planning material requirements but has shortcomings in execution. MRP relies on the forecast of the product demand leading to uncertainty, bad inventory performance and service level, system nervousness, high operation cost, and visibility deficiency resulting in a bullwhip effect.

Furthermore, in a manufacturing environment, MRP factors the modalities of demand. Hence it has been deemed suitable for inventory management, which is subject to demand, as it is independent of assumptions about demand patterns and inventory behavior. Therefore, the objective of MRP methodology is to determine and factor out the gross and net requirements of needed materials for production through its ability to generate the required information of the needed items for the proper inventory order action, which in turn falls back to procurement and usage of the materials for production purposes. (Ptak and Smith, 2011)

3.2.1 System Input and Outputs

A proper and intelligent MRP system demands specific functional input from various data sources. These inputs include the master production schedule, demand forecast, external spare parts orders, inventory record documents, and product structure documents. Based on this imputed data, the MRP system will provide the expected desired output. Outputs include rescheduling notices, orders to be released, and planned orders for the scheduled products to be released for future purposes. (Ptak and Smith, 2011)

Figure 5 illustrates the required input to the MRP system to yield the desired output or result. These inputs consist of an independent demand forecast, MPS, external orders or components, inventory record file, and product structure file. The master production schedule expresses the overall production plan. It also serves as the primary input of the MRP system based on its main functionality, being that it defines the entire manufacturing program of a plant. Hence it contains the products to be produced with the order components, which originate from external sources alongside items forecasted subjected to independent demands. The external originating orders comprise interplant orders, service part orders, and the manufacturer's OEM orders used for particular purposes. The forecast and independent demand utilize some statistical techniques to perform functions for system programming with regard to the demands made outside the MRP systems. The inventory record files, and product structure files are both information files imputed into the system concerning inventory records and bills of materials. With this inputted information, a company is expected to generate the desired service outputs, such as order release notices and planned orders scheduled to be released in the future. (Ptak and Smith, 2011)
3.2.2 MRP Limitations and Organizational effect

MRP planning methodology has been discovered to portray shortcomings, ultimately negatively affecting the organization. These shortcomings are primarily a result of the continual change in a global manufacturing environment and the market's volatile nature, as previously explained in section 1.2. As such, the company faces these challenges by having undesirable outcomes and frequent shortages of materials at various stages of production, procurement, and fulfillment cycles. The resultant effect of these shortcomings can be viewed from planning and inventory management perspectives. First, there tends to be an unacceptable inventory performance by which the company witnesses either a few suitable materials or too many unwanted materials, high obsolescence, and low inventory turnout. Then, there is also the tendency of an unacceptable service level performance due to the company's inability to perform in terms of on-time delivery, low fill rate, and poor customer satisfaction. There are high expedite-related expenses and waste-cost-related challenges, as the company tends to pay more than necessary to meet the customer's demands, such as adding additional freight charges or hiring more workers as the project progresses. In the long run, these shortcomings affect the business-customer relationship, which could significantly impact the manufacturing business environment. (Ptak and Smith, 2011)

A further illustration was given by Ptak and Smith (2011) as portrayed in Table 2 below, which emphasizes the individual attribute with regard to planning, inventory, or stock management attribute and their resultant effect on the organization.
Table 2: MRP impact in manufacturing organization (Adopted from Ptak and Smith, 2011)

<table>
<thead>
<tr>
<th>Typical MRP Attribute</th>
<th>Effect to the organization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PLANNING ATTRIBUTE</strong></td>
<td></td>
</tr>
<tr>
<td>Future demands qualifications are constricted, and exhibits early warning indicator of possible stock out or a spike in demand</td>
<td>Inventories and waste capacity becomes inflated with future demand by the planners which in turn makes the environment to be extremely vulnerable to spike. Also, this creates the need for large amount of data for the spikes to be qualified</td>
</tr>
<tr>
<td>Constant release of manufacturing orders irrespective of the availability of component part</td>
<td>Shortages creates delays in production process even though the manufacturing orders are released to the floor, hence an increase in WIP, regular priority and schedule changes, delays and overtime.</td>
</tr>
<tr>
<td>The use of forecast method or MPS to determine the parent and component level of net requirement</td>
<td>Consequently, part of planning relies on these forecasted demand trends to generate a “push” requirements, forecast methodology tends to be inaccurate and unreliable hence promoting a misalignment with market demand which could ultimately result to inventory increase with unwanted items</td>
</tr>
<tr>
<td><strong>STOCK MANAGEMENT ATTRIBUTE</strong></td>
<td></td>
</tr>
<tr>
<td>Parameters such as safety stock, fixed order quantity and order point do not adjust to actual market demand or seasonality</td>
<td>Forecast tends to inaccuracies leading to increased expediting</td>
</tr>
<tr>
<td>The due dates controlled by the priority of orders</td>
<td>Actual priority will not reflect, as it’s not measured by due dates hence the difficulty in determining the relative priority between stock orders</td>
</tr>
</tbody>
</table>

However, The MRP-II methodology is employed to adjust and execute the smooth functioning of the plants and organizations. It involves integrating the manufacturing processes, including people, materials, equipment, and finance. This MRP II methodology is a follow-up of the MRP system. The MRP methodology involves the manufacturing materials, whereas MRP II integrates the whole manufacturing and production process. MRP II gives the precise requirements of items on the shop floor, the material type required, the quantity of raw material required on the production line, labor needed, sequence, and time needed for manufacturing. In addition, it has the following features, master production schedule (MPS), item master data, bill of Materials (BOM), production resources data, inventories and orders, purchasing management, shop floor control, capacity requirement planning, and cost Management. The limitation of the MRP II system is that the initial running operation is expensive and consumes time. The MRP initial processes must be full proof for quick execution of data. (Charudatta et al., 2018)

3.2.3 The distinction between MRP and DDMRP
The concept of DDMRP was known in 2011, but not enough literature is available. However, different research has studied the outcomes of MRP and DDMRP in the manufacturing environment. Precise BOM, accounting system, and inventory management system are the similarities required between DDMRP and MRP (Ptak and Smith, 2011). Miclo et al. (2016) noted that DDMRP is more efficient and stable than MRP in complex supply chains with fluctuating demand, inaccurate forecasts, lengthened lead times, and complex networks. Also, a stock-out analysis clearly distinguishes between these two systems. Occasionally, stock-outs with uncertain demand were noticed on the MRP system, while there were no stock-outs for inventory for the DDMRP system (Shofa and Widyarto, 2017).
MRP has more significant shortages and requires schedule changes than DDMRP. For some items, it was observed in MRP systems that an overstock situation was noticed (Shofa and Widyarto, 2017). In seasonal demand variation, DDMRP performs better as the stock level are flat instead of the normal distribution, while where demand is constant and few forecast over a short duration, MRP performs better, and safety stock (SS) make up for the variability in the forecast (Miclo et al., 2016). Weekly buckets and flattening the bill of material are the different methods firms use to surmount the inherent challenges of nervousness in the MRP system, still, the situation remained unchanged (Ptak and Smith, 2016).

3.3 Enterprise Resource Planning

The ERP is a software-based system that incorporates all operating units of the enterprise collaboratively. It is a system that tracks, gathers, and integrates all collected data and information in various enterprise domains and functional units. In this way, information can flow better between inventory, production, planning, materials, engineering, finance, human resources, sales, and marketing. The sole outcome of ERP implementation could result in a high-quality service, improved communication, lead time reduction, facilitating decision making, higher productivity, and lower costs, which would, in turn, enhance customer service by increasing sales, as well as increase profits, (Abd Elmonem et al., 2016). The ERP systems are modified to improve productivity by improving the firm's ability to pass necessary information across the firm and its supply chain channel. When an ERP system is successfully implemented, it can enhance lower inventories, increase customer satisfaction and efficiency, and reduce the product development cycle (Beheshty and Beheshty, 2010).

The system is comprehensively designed to integrate several business units and functionalities to visualize the business from a single information perspective. The ERP systems evolved, upgrading their processes and enhancing functionality by increasing their integrating capabilities. The system is considered cloud-based due to the influence of cloud computing which could be accessed using an internet browser without installing or configuring the systems from the user’s end. This method has its benefits as well as several challenges. With this, manufacturing planners seek a solution that could yield optimum results concerning material planning. As a result of ERP, information can be exchanged and clarified synchronously, making it possible for the information to be distributed along the supply chain, inventory management to be improved, and distribution to be viewed as an essential holder of supply chain expertise.

According to Umar et al. (2016) , ERP has been considered as not suitable enough for optimal results based on technological advancement from other countries. As such, there is a nonavailability of specific guidelines for developing countries as a low percentage of global research is assigned to these developing countries. Another challenge with the ERP approach is the complex implementation process and high failure rate as witnessed by most users. These concerns prompt scientists and manufacturing planners to seek an optimal solution regarding material planning. Hence the advent of DDMRP, as ERP systems shares some similar features with the traditional MRP. Figure 6 below shows the characteristic nature of an ERP system concerning its connectivity between the customer and its suppliers. It illustrates ERP as a software system used to integrate all functional units of the enterprise, such as manufacturing, distribution, logistics, materials, and sales, collaboratively and cooperatively. This was a supposedly proper way of planning in regard to manufacturing, but with the challenges mentioned above, planners anticipated a transformative and improvised way to carry out their operations, hence making ERP partially obsolete.
3.4 Just In time (JIT)

The JIT concept is used in manufacturing to eliminate waste and to improve productivity continuously. The JIT philosophy is an effective method of managing inventories. In Japan, this idea was first presented as Kanban. By using this technique, processing waste is to be avoided. Furthermore, by using JIT, many businesses increase their productivity. In this idea, the materials and components are delivered to the workstation just when they are needed. Just-in-time is a crucial tool for controlling the purchase and distribution of manufacturing companies, and it requires intensive supply chain management to avoid disrupting the production schedule. The purpose of the JIT Philosophy initially is to reduce waste brought on by excessive production, waiting, excess inventory, strict quality control, and customer devotion. JIT inventory aims to prevent inventory from exceeding demand and finds storage facilities for the additional inventory. When adopting the JIT method, manufacturers want to use materials in production at levels that satisfy distributor or retailer demand while avoiding excess. (Franco and Rubha, 2017)

JIT is a continuous improvement aimed at waste removal by various means, either by only producing what is needed, cutting, and reducing setup and lead times, changing amounts, and controlling the process to help prevent this. Furthermore, The JIT is characterized by specific features, such as promptly providing high-quality inventory and facilitating the availability of a modest amount of inventory at the right time, which lowers the expenses associated with holding it. (Mankazana and Mukwakungu, 2018)

Although the initial ideology behind JIT was to eliminate waste and to improve productivity continuously, and it was initially regarded as an efficient MPC approach, it had shortcomings. As per several findings, it was determined that the JIT is sensitive and vulnerable to demand variation because the JIT operates without buffers. This ultimately causes the supply chain to be fragile and less agile. As a result, the JIT system required the essential features from the standard MPC system, including production planning, MRP, and MPS, in order for it to cope with variability. (Kortabarria et al., 2018)
3.5 Inventory Management

One of the problems manufacturing firms face is inventory. Inventory can be referred to as a raw-material for production or stock of goods to be sold (Samak-Kulkarni and Rajhans, 2013). Most manufacturing organizations face the risk of not keeping up with the demands of their customers without inventory and when the demands of stock are low, inventory increases due to unused stock. Inventory control is vital in manufacturing firms because inventory holding cost can attract severe financial implication, therefore firms need to reach an optimum point between inventory and customer’s demand. An inventory system is a band of policies that control and monitor the quantity and level of inventory (Duan and Liao, 2013). Inventory management system ensures the right quality is obtained and at the right time, that is optimal inventory level that must be available before a supply is made and quantity to order (Samak-Kulkarni and Rajhans, 2013).

Production process will be halted due to lack of inventory, it shows relevance of inventory on manufacturing organizations. Too much holding of stock in storage will lead to increase in holding cost, at same time low inventory in the warehouse, the firm will experience a stock lost. Manufacture firms need to consider the inventory control separately in each of the production steps and develop policies. (Hung, 2016)

Inventory management is a significant process in operation management when the manufacturer’s perspective within the supply chain is considered. The firm procures raw materials from suppliers for production purposes, holds the goods in storage according to the production schedule, and subsequently holds the finished goods for some time. The relevance of inventory management should not be underestimated, given the manufacturer’s functions in the supply chain. Ideally, the main goal of the manufacturer is to maintain the inventory level as shallow as possible concerning inventory purchase and holding costs. In order to achieve this, the amount of purchased or produced items during the initial period should be able to meet the required demand for that period. Successful inventory management should center on the minimization of inventory costs while still keeping to customers’ demands and service levels. The demand, replenishment, lead time, and cost factors affect inventory management decisions. (Akyurt, 2016)

3.5.1 Inventory control system: re-order, review, and order policies

Inventories are controlled at an optimum point to cover fluctuations in sales demand and production fluctuations as too little inventory led to sales loss and high working capital when inventory is high. To get optimal inventory, it is required to determine at what point the stocks must be added to sustain inventory at the optimum point. The point of adding inventory to the continuous review policy is done when the inventory level has reached the reorder point (ROP) point.

In inventory management, the inventory reorder point (ROP) is the lowest limit stock level for a specific product. It triggers the reordering of stock when it reaches the stock level of that product. A graphical illustration of the process is displayed in Figure 7 below, indicating an inventory level’s reorder point as a time function. Inventory ROP ascertains the lead time required to restock the product, which allows the manufacturer to hold on for new stock, so the ordering of goods is done right on time. The ROP quantity indicates the inventory level initiating the additional stock order. Safety stock, referred to as buffer, is the quantity that keeps the manufacturing firm from stockouts. (Shukla and Jangde, 2017)

According to Shukla and Jangde (2017), there are three factors that are important in determining the reorder point. These factors are the quantity demand centered on the inventory used or sold daily. The second factor is the lead time which has to do with the duration it takes for an order placed to arrive. And lastly, the safety stock is the inventory quantity kept against unforeseen circumstances like an increase in demand or delays in lead time.
Figure 7: A Typical re-order point system (Modified from Axsäter 2015)

Figure 7 above depicts a typical re-order point system, which shows the regular inventory behavior and replenishment pattern whenever a customer orders at batch Size Q. Inventory fall from point A to B until point B. The stock is replenished in Q1 once the level drops below the re-order point. This is repeated at point CD and EF, as indicated in the diagram above which, in the long run, will impact the supply chain regarding the availability of raw materials for replenishment purposes.

3.5.2 Inventory review policies

The inventory review policy involves monitoring and managing inventory situations to determine when the next replenishment will occur. There are two methods in this regard. Continuous review policy and periodic review policy are the two policies of Inventory management policies in companies with random demand fluctuations. Periodic policies are cheaper in terms of cost than continuous review policies but in sustaining the required service level from slow moving material continuous review are useful. (Axsäter, 2015)

- **Continuous review**
  
  Continuous review refers to monitoring inventory levels constantly to ensure that they remain within a certain level or threshold level and automatically placing an order for new inventory to be replenished once the minimum level is reached. In this case, all information about the inventory level is known, and the inventory is replenished based on this information. (Axsäter, 2015)

- **Periodic review**
  
  In this scenario, the information about the inventory status is unknown, but the inventory level is monitored or inspected over a period interval, either on weekly or monthly basis. Therefore, the inventory review and replenishment are done once the fixed period expires. (Axsäter, 2015)

3.5.3 Different ordering policies

The ordering policies are the deterministic factors by which an organization’s managers or procurement personnel place an order for a required quantity for inventory replenishment. The (s, S) and (R, Q) policies are the required policies used in this case, as depicted in Figure 8 and Figure 9 below.
The (R, Q) policy is represented below, where R depicts the Re-order point, which refers to that stage of inventory management in which the inventory needs to be re-ordered to satisfy customer demand and production. This ensures that the company can have the minimal required product quantity (Q) in storage to prevent disruption in operational activities and avoid stockouts. Figure 8 illustrates a condition in which a new order quantity is triggered whenever the inventory level reaches a fixed re-order point R.

![Figure 8: R, Q Inventory policy (Modified from Axsäter 2015)]

Figure 9 represents the (s, S) policy, where s indicates the point where a re-order should be made, and S indicates the order level up to that point (a fixed upper bound). Orders are placed when the inventory drops below the re-order point s, with the order quantity equaling the difference between the order level S and the previous order level (Axsäter, 2015).

![Figure 9: S, s Inventory policy (Modified from Axsäter 2015)]

**3.5.4 Economic Order Quantity**

The Economic order quantity (EOQ) is a classical replenishment concept of production and Inventory management that existed for a very long time before the modern era. The idea behind this concept is to determine a suitable batch quantity. The EOQ can otherwise be regarded as a traditional production scheduling model aimed at determining the optimal quantity that should be procured to minimize carrying inventory and order processing costs. It is a well-known concept in inventory
management used by various manufacturing organizations to calculate the quantity (Q) with regard to holding and ordering costs. (Axsäter, 2015)

Five assumptions are made to determine the EOQ, and they are listed as follows

1. Demand is constant and continuous.
2. Associated costs are constant.
3. Quantity can be more than just an integer in a batch.
4. Batches are received simultaneously.
5. A shortage is not acceptable.

The below formula is used to determine the quantity to be ordered and its given as thus:

\[ Q = \sqrt{\frac{2KD}{H}} \]

*Equation 1: The Economic Order Quantity*

Where:
- \( K \): Ordering cost
- \( D \): Demand per unit time
- \( H \): Holding cost per unit/unit of time
- \( Q \): Optimal order quantity/batch size. (Axsäter, 2015)

### 3.6 Bullwhip Effect

The bullwhip effect is said to be built up when there is an amplification of demand order variabilities in the supply chain, giving rise to distortion of information, which could, in turn, have a negative effect on the supply chain. Such distortion could result in inefficiencies such as excess inventory investment, poor customer service, lost revenue, misguided capacity plans, and missed production schedules, (Ji et al., 2015). This frequently causes information to be distorted, which results in an ineffective supply chain (Baur and Frazzon, 2018). Poor customer service, missing production deadlines, and income loss are just a few examples of inefficiencies that might occur (Kholidasari et al., 2019).

The bullwhip effect has a detrimental impact on the supply chain, increasing inventory costs, affecting overall supply chain costs, decreasing product availability, and decreasing revenue. Such a situation emanates from improper miscommunication of system flow. Minor modifications to a customer’s orders can accentuate an increase when the data is transmitted upstream of the supply chain’s order quantity. The term “bullwhip effect” is used when this happens. The demand for information in the supply chain is shown in Figure 10 below, and when manufacturing enterprises upstream lack knowledge of genuine, specific customer wants, the supply chain may become inefficient. Consequently, the bullwhip effect impacts the supply chain’s effectiveness. (Jeong and Hong, 2019)

According to Wang and Disney (2016), the bullwhip effect is the amplitude of order volatility along the whole supply chain. Therefore, by analyzing the variance between real needs and orders, the bullwhip effect can be identified when this term is taken into consideration (Wang and Disney, 2016).
The Figure above depicts the bullwhip effect situation within the supply chain. It shows the distorted movement from and to the opposite direction, with distortion of relevant information moving from left to right, while that of relevant materials from right to left. This distorted movement tends to be amplified progressively by transferring across the supply chain. The implication is that the company lacks the appropriate materials needed for production, which could impact the organization negatively in terms of cost. Hence the need for a solution to advert such a challenge which may as well be triggered by system nervousness and complexity. (Ptak and Smith, 2016)

3.6.1 Causes of Bullwhip Effect.
According to Croson et al. (2014), The bullwhip effect can be triggered by several factors forcing it to disrupt the supply chain. Over time, supply chain managers dealing with the persistence of the bullwhip effect have been able to decipher the challenges from two perspectives providing the supply chain managers with the needed information concerning the challenges, hence setting the pathway to mitigating these challenges. These factors can be viewed from two different perspectives, which are categorized as either behavioral causes or operational causes.

3.6.2 Operational Cause
Operational causes pertain to the institutional and physical setting. The physical structure manages transportation, manufacturing delays, and the distribution of goods along the supply chain. The coordination of businesses and the flow of information among decision-makers are both impacted by institutional structure. The operational causes comprise of demand forecasting updating, rationing and shortage gaming, ordering policy and batching, price fluctuation, and lack of transparency. (Croson et. al., 2014)

- **Demand forecasting updating**
  This concerns the predictability of demand amplification occurrences due to a longer lead time and safety stock. It further implies the building up of safety stock based on forecasted orders and transmitted along the supply chain prompting the building up of the bullwhip effect (Paik and Bagchi, 2007). A supply chain's end experiences chaotic reactions due to repeated modifications. Order managers use resupply rules to stabilize and streamline orders placed in the supply chain (Chiang et al., 2016). The market is generally different from what the decision-makers respond to; instead, they usually respond to stabilized commands from actors downstream. Logistics managers higher up the supply chain respond to stabilized orders when actors in the supply chain employ single-echelon inventory optimization to
optimize and forecast inventories. The supply chain forecasting technique strongly influences the bullwhip effect. This may lead to demand irregularities that sometimes match the actual demand (Jeong and Hong, 2019). Chaing et al. (2016) showed that choosing forecasting techniques affects the bullwhip impact, as specific techniques have more substantial impacts.

- **Ordering policy and batching**
  In this instance, orders are placed periodically, creating a surge in demand at a specific time, followed by the period in which there are few or no orders and other periods with enormous demands. When compared to swings in consumer demand, order variability is amplified most by ordering policy and batch sizes. There are two different batching methods that can be used. They are order quantity-based batching and time-based periodic batching (Wang and Disney, 2016). Orders are placed over a period in a process called time-based batching. Implementing an economic order quantity (EOQ) ordering policy frequently leads to the second kind, which is based on order quantities (Wang and Disney, 2016). Another crucial factor is the batch size. Because the ordering cycles are not evenly dispersed, bullwhip effects occur when manufacturers utilize a periodic orderly scheme.

- **Rational and shortage gaming**
  In this scenario, products are rationed by the manufacturers based on the orders made by the customers, this usually occurs when the demands of these products are significantly over the supply. With these policies in place, the customers tend to place orders more than what is required, further prompting distortion of information because of the excessive ordering without considering the already placed orders that have not been received by the customers. (Paik and Bagchi, 2007)

- **Price fluctuation**
  Price reductions, discounts, promotion, and other unique market incentives lead to forward buying. These situation cause customers to place orders for more product than they actually need, hence prompting more variability and demand irregularities which further enhances bullwhip effect. (Paik and Bagchi, 2007)

- **Lack of transparency**
  It is beneficial to exchange data on prior customer demand and planned order requests further down the supply chain to lower the chance of a bullwhip rising (de Almeida et al., 2015). Information sharing results in a reduction of the bullwhip effect, while information distortion increases it. Real-time information sharing reduces the bullwhip effect and associated expenses for the manufacturer in a supply chain (Jeong and Hong, 2019).

### 3.6.3 Behavioral Causes

On the other hand, behavioral causes include the criteria on which the logistics managers base their choices. The attitudes of the decision-makers, characteristics of other actors, and procedures used to assess data and make decisions on products, capacity, and planning are all included in this list of behavioral causes. The bullwhip effect's behavioral reasons result from making bad decisions, which will have an adverse effect on supply chain effectiveness. (Croson et al., 2014)

- **Coordination risk**
  This can be inferred as one of the main subjects under the bullwhip effect's behavioral causes (Croson et al., 2014). The coordination risk develops when supply chain participants believe the other participants will not act as they should and respond by placing excessive orders. A decision-maker unsure if the partners would issue the wrong commands or make the wrong choices may decide to deviate from the original plan to provide a safety net against bad behavior. This will cause the demand for the suppliers to change (de Almeida et al., 2015). The supply chain may become unstable as a result of these deviations.

- **Instability and trust**
  Many supply chain choices, especially significant ones, need to be discussed with partners with the technical know-how to increase the efficiency of the supply chain. This is why it is
crucial to have confidence in one's abilities while making selections because poor choices frequently result in higher costs and worse performance. Similarly, competence and performance pledges constitute the foundation of supply chain confidence. For example, when logistics managers discover that their suppliers are unreliable, delivery estimates are not reached, and the client obtains an inferior product to what was ordered. (de Almeida et al., 2015)

Neglecting time delays
Logistics managers fail to consider system non-linearity, appropriate feedback, and time delays. The logistics managers then tend to base their orders on the gap between the amount of stock they now have and their target level without taking into account the orders that have already been placed, which leads to instability and changes in placed order volumes. (Croson et al., 2014)

Fear of empty stocks
Each node’s logistics manager might place excessive orders out of concern over running out of inventory and losing clients. This tendency might result in a bullwhip effect and a significant variance in order sizes. In addition, when demand increases and the supplier cannot speed up production, products become limited, and consumers are given priority over others. So, there is a longer lead time. (de Almeida et al., 2015)

Responses of the logistics manager
Logistics managers frequently respond to inventory declines throughout the supply chain and impending backlogs. Managers place a wave of orders that gets bigger at each node in an effort to lessen the number of backlogs. This influx of orders will overshoot the inventory target while reducing stock-outs. From a cost optimization perspective, these overshoots are unacceptable. Managers will control the inventories by abruptly ceasing to place new orders when the inventory peaks and then gradually declines. (Croson et al., 2014)

3.6.4 Measures to Counter Bullwhip Effect.
The bullwhip effect significantly impacts supply chain management. Thus, it is crucial to investigate countermeasures to stop or lessen this bullwhip effect in the supply chain. Avoiding numerous updates, breaking order batches, stabilizing pricing, and eliminating gaming in scarcity are the four techniques that can be used. (Wang and Disney, 2016)

Avoiding multiple updates
Increased order quantity variability and uncertainty in demand forecasting are both caused by longer lead times. Therefore, streamlining operations, cutting lead times, and lowering order quantities can all help to lessen the bullwhip effect. Demand volatility is somewhat lessened as lead times are cut down. Additionally, using inventory data can aid the supply chain upstream in better anticipating and preparing for changes in inventory requirements downstream and fulfilling the goal of reducing the bullwhip effect. (Wang and Disney, 2016)

Break order batches
Batch ordering frequently results in the bullwhip effect, negatively impacting the entire supply chain. Since order batching results in the bullwhip effect, manufacturing companies must find a technique to place orders in smaller batches or frequently reorder. The expense of transportation contributes to large order batches as well. Using 3PL and third-party logistics firms will reduce the need for regular supplier replenishments, and small batch replenishments are cost-effective. (Wang and Disney, 2016)

Stabilize prices
Another factor contributing to the bullwhip effect is the high-low pricing, delivery, and purchasing being out of sync. Discounting is the most straightforward method of preventing the bullwhip effect by lowering both the frequency and the magnitude of wholesale prices. It also entails creating effective price tactics to entice retailers and lower pre-purchasing behavior. (Wang and Disney, 2016)
• **Eliminate gaming in shortage**
  When a scarcity emerges, the supplier should implement rationing strategies based on historical sales data rather than current orders, as this removes the motivation for customers to place inflated order volumes. Additionally, exchanging capacity and inventory information between the producer and the customer helps to soften customers' feelings and reduces their urge to play games. (Wang and Disney, 2016)

### 3.7 Theory of Constraint (TOC)

The theory of constraint approach is a plant scheduling concept that has been implemented by manufacturing organizations over time prior to the emergence of DDMRP. At first, the approach was inferred to as a substitute for the integrated MPC system, and it is characterized by most of the MPC functions (Jacob et al., 2011). The TOC approach spotlights the necessity of enhancing the performance of a system by leveraging the bottleneck. A bottleneck in the sense that when a capacity is less than or equal to the expected demand. A constraint such as this, is experienced by most firms; hence TOC emphasizes how these constraints are utilized based on the set target by the individual firm and the resulting impact on the system after the constraint is exploited. The main ideology behind this concept, however, is to maximize throughput by enhancing the performance and efficiency of the system by simply pinpointing the bottlenecks in the system (Mohammadi and Eneyo, 2012).

TOC is likened to a management methodology that is based on system thinking. Essentially, this concept corresponds to the idea that every system has some constraint or bottleneck which limits its performance, and the presence of constraint gives opportunities for improvement of its system performance. Highlighted below are the five process steps of the TOC methodology, which enables the organization to make the right decision to identify and eliminate constraints, which are described as highlighted below.

- **Identify the system bottlenecks**
  These bottlenecks may be managerial or physical, which consist of man, materials, and equipment. It is necessary to prioritize these bottlenecks and their effect on the manufacturing firm's goals. (Orue et al., 2021)

- **Determine how to exploit the system bottlenecks**
  When the bottleneck is managerial, it should be eliminated and put in place with a policy that will increase the turnout if the physical bottleneck is to make the bottlenecks as effective as possible. (Orue et al., 2021)

- **Ensure everything is subordinate to the above decision**
  This means that every other constituent of the system's non-bottleneck must be modified to assist the optimal effectiveness of the bottleneck. If non-bottleneck resources are used beyond their productive capacity to support the bottleneck, they do not improve the output but increase unnecessary inventory. (Orue et al., 2021)

- **Upgrade the system's bottlenecks**
  Rigorous improvement on existing bottlenecks will improve their performance, and the potential of non-bottlenecks resources is better realized with improved bottleneck performance. (Orue et al., 2021)

The steps will be repeated from step one when a bottleneck is found in the previous step (Orue et al., 2021).

Furthermore, TOC is a continuous process from the first part, with the second part illustrating that every situation has its solution. Business environments change over time, so firms need to be aware of that. Also, one of the Key characteristics of the TOC in terms of performance is the ability to enhance revenue increase while decreasing inventory, lead time, and cycle time, providing a substantial source of competitive advantage. This approach serves as a replenishment method for
resolving challenges about distribution and supply. TOC proposes the TOC-SCRS approach, called the theory of constraints supply chain replenishment systems, to counter these challenges. The replenishment system is characterized by decreasing inventory level, lead time reduction, decreasing transportation cost, and increasing forecast accuracy and customer service level. However, the TOC approach also exhibits some shortfalls, such as its inability to incorporate BOM explosion and its difficulty determining replenishment frequency. (Kortabarria et al., 2018)
4. Demand Driven Material Requirement Planning (DDMRP)

Demand Driven Material Requirements Planning was described by Ptak and Smith (2016) as an inventory structure generational, an operational set and execution system that uses critical decoupling, controlled inventory, time, and quantity buffers to plan for material and instructions within an operational scope. Demand Driven MRP is a recent model that deviates from the cost-based functional approach and prioritizes existing demand and flow. The DDMRP approach’s main aim is to transform the supply chain from Push to pull based on actual demand and eliminate the bimodal effect (Pekarčíková et al., 2019). The target is on existing demand and the capability to use actual demand obtained from the operation of buffers or, more technically, decoupling points. Demand-driven sales and operations process is a vital parameter that demand-driven operates to meet the critical function and market objectives while reducing running capital and expenses (Ptak and Smith, 2016). DDMRP is derived from different methodologies, including MRP, Lean production, and Theory of Constraints, combining elements from these methods exclusively. The creation of DDMRP became necessary due to the rising complexity of manufacturing planning. A significant aim of DDMRP is simply adapting to the highly volatile and variable manufacturing environment, which the previous traditional planning approach could not handle. A key performing criterion for this method is based on lead time compression, service level increment, and aligning efforts to market demands. The approach implored includes careful synchronization of planning, scheduling, and execution of material consumption (Kortabarria et al., 2018).

As indicated in the Figure 11 below, DDMRP’s foundation is based on six pillars. These pillars, such as MRP, lean manufacturing, distribution requirement planning, theory of constraint, six sigma, and innovations, are all used in the industrial practices in today’s industrial world. The strength and potency of DDMRP as a practical planning and execution methodology rest on the individual characteristics of these pillars, which is the main reason for these linkages. (Pekarčíková et al., 2019)

The study by Miclo et al. (2019) likened DDMRP to be a hybrid system composed of four integral subsystems, namely, MRP, distribution requirements planning (DRP), lean, and theory of constraints (TOC). Figure 11 below illustrates the system of Demand Driven MRP. Demand-driven MRP may be a dynamic and effective demand-driven solution to answer the challenges of today’s manufacturing landscape. Through innovative approaches in inventory and product structure analysis, new demand-driven planning rules, and integrated execution tactics, DDMRP is intended to tie material availability and provide to actual consumption throughout the bills of materials (BOMs). When used holistically across a supply chain, it removes the cascading and compounding disruptions that almost all supply chains face.

Furthermore, this approach may be a prerequisite to using and sustaining pull-based scheduling and execution methods. DDMRP encompasses a way to incorporate required elements of strategic planning within the sales and operations plan with little exposure to the variability and volatility experienced with traditional forecasting methods. From the MRP method, DDMRP pulls the demand, product increase, and time, lean system conception of waste, variance and the draw in flow are modified, also DRP (Six Sigma), the outlier variance logic executable adaptive adjustments is taken and then TOC, it takes the idea centering on constriction, inventory acceptance and strategic position. (Miclo et al., 2019)
4.1 Demand Driven MRP Components

DDMRP comprises of five components, as illustrated in Figure 12 below. The initial trio components primarily state the basic and developing structure of a demand driven MRP methodology while the final two parts state the running operation of the method. Ptak and Smith (2016) noted that exempting any of these components will diminish the value of DDMRP solutions in manufacturing firms which is vital in eliminating MRP shortcomings. The components are strategic inventory positioning, buffer profiles and levels, dynamic adjustment, demand driven planning and visible and collaborative execution.

4.1.1 Strategic inventory positioning

Strategic inventory positioning is the number one step in DDMRP which examines where inventory needs to be placed. Manufacturers and customers always contemplate in determining the number of products to be produced as well as the time required to meet demand. The strategic inventory position plays a critical factor in this scenario. This is done by evaluating potential locations financially to see if the chosen location or position is advantageous for production flow for a particular item on the BOM. Choosing these points aims to provide the most excellent flexibility and the shortest lead time. These inventory positions are also referred to as decoupling points. Decoupling allows two-way gain, and it either justifies the demand signal error or the supply cohesion variability. The efficiency of the organization’s supply chain is significantly impacted by where decoupling points and their respective buffers are positioned as it tends to attest to the cash flow, return on investment, and the
quantity and quality of service. A suitable inventory position is determined based on the manufacturing lead time (MLT) and the cumulative lead time (CLT). Although achieving these lead times in today’s complex manufacturing environment becomes difficult, making the lead times realistic becomes necessary and only achievable under two extremes. For the MLT to be made realistic planning input, it is essential to stock and manage all available components at every level. More so, to make the CLT a realistic planning input indicates that no component part in the longest path will be stocked. In strategic positioning, a practical lead time referred to as actively synchronized replenishment lead time (ASR lead time) is the critical point between the MLT and the CLT and is required to be calculated for a realistic analysis of inventory positioning. Hence the ASRLT is defined as the longest unprotected or unbuffered sequence in the BOM, and this is the core concept of DDMRP, being a vital tool in determining the best conditions of inventory level, lead time reduction, and factors in determining the realistic due dates. (Ptak and Smith, 2011)

Furthermore, Ptak and Smith (2011) highlighted some positioning factors that are systematically applied across the entire BOM, manufacturing environments, and its entire supply chain, which determines the most suitable positions for items, either manufactured, purchased, or finished goods, with the inclusion of servicing parts. This solves the puzzle and gives most organizations the required knowledge of where and how to place items. These factors are listed and defined in Table 3 below.

<table>
<thead>
<tr>
<th>Table 3: Strategic Inventory positioning factors (Adopted from Ptak and smith, 2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td>customer Tolerance Time</td>
</tr>
<tr>
<td>Market Potential lead time</td>
</tr>
<tr>
<td>Demand variability</td>
</tr>
<tr>
<td>Supply variability</td>
</tr>
<tr>
<td>Inventory leverage and Flexibility</td>
</tr>
<tr>
<td>Critical Operation protection</td>
</tr>
</tbody>
</table>

4.1.2 Buffer profiles and level

The next phase is about determining the needed amount of protection at the decoupling point, hence the idea behind this is conditioning the inventory level to an ideal state, as too much inventory would result in excess expenditure, capacity, material, and space to store inventory. Alternatively, when the inventory is too little, the company tends to face frequent shortages resulting in missed sales targets and costly rush orders (Kortabarria et al., 2018). This brings into question the dual inventory behavior, as an inventory could either be an asset or a liability as indicated in the diagram below. Prior to determining the buffer level, a company should be able to investigate the possibility of inventory being either an asset or liability, inventory can be considered an asset when it could satisfy the available market and customer demand requirement, otherwise, it is then said to be a liability due to shortages regards to production planning.

As displayed in Figure 13 below, an inventory can be regarded as an asset once it has the ability to fulfill the needed customers and market demands and liability if it shows otherwise. In the real sense, service levels can be reduced due to inventory shortage, as this can, in turn, affect the company’s
performance. In the event of surplus inventory within a company, however, capacity, capital, and space will be needed. This, in turn, can have a severe cost implication for the company, thereby hurting its balance sheet. To avoid stockouts, the raw materials should always be greater than zero, hence should never be less than zero. Managing and buffer build-up will be discussed in the next section. (Ptak and Smith, 2011)

For DDMRP to minimize demand variability and supply variability, a buffer position and strategic replenishment are required (Shofa and Widyarto, 2017). This idea was derived from the conventional inventory management system with regards to the seasonal level inventory into three color-coded zones, which make up the total buffer as described in the next section below. In order to calculate the required buffer for each profile (G, Y, and R), the Average daily usage (ADU) over the percentage of lead time must be known, hence as denoted by the formulas below.

\[
\text{Green zone (GZ)} = ADU \times \text{Leadtime} \times \text{GZ Leadtime Factor}
\]

\textit{Equation 2: The Economic Order Quantity}

\[
\text{Yellow zone (YZ)} = ADU \times \text{Leadtime}
\]

\textit{Equation 3: The Yellow zone equation}

\[
\text{Red zone base (RZ)} = ADU \times \text{Leadtime} \times \text{RZ Leadtime Factor}
\]

\textit{Equation 4: The Red zone base equation}

\[
\text{Red zone Safety} = \text{Variability Factor} \times \text{Red zone base}
\]

\textit{Equation 5: The Red zone safety equation}

The buffer zone is calculated assuming the top of red equal to red zone

\[
\text{Top of yellow} = \text{Top of Red} + \text{Yellow zone}
\]

\textit{Equation 6: The Red zone safety equation}

\[
\text{Top of green (TOG)} = \text{Red zone base} + \text{Red zone safety} + \text{Yellow green} + \text{Green Zone}
\]

\textit{Equation 7: The Red zone safety equation}

Furthermore, the total buffer consists of three universally color-coded zones, which include green, yellow, and red. These zones will ascertain the planning and process priorities. For example, green shows an inventory stand that needs no action; yellow shows an inventory position that needs replenishment; and red refers to an inventory position that needs special attention (Ptak and Smith, 2011). Figure 14 below illustrates the zone stratification within a stock buffer. Two other color-coded
zones are added to the intuitive zones mentioned in Figure 15 below. These additional zones, however, do not affect the actual buffer sizing calculation but are determined after the buffer calculations are made. The light blue zone represents the overstock position or over top of green (OTOG). This zone can sometimes be referred to as the white zone. Also, the other color-coded zone represented in dark red signifies an out-of-stock situation with demand, sometimes referred to as the dark zone.

![Diagram](image)

**Figure 14**: Moving to zone stratifications in a stock buffer (Adopted from Ptak and Smith, 2011).

**Figure 15**: Meaning of each buffer zone (Adopted from Ptak and Smith, 2011)

Figure 16 shows the inventory asset-liability curve with the overlaid color-coded zones. Kortabarria et al. (2018) explains the zone sizes, which were mentioned to be determined by factors such as delivery lead time, average daily usage (ADU), and Minimum order quantity (MOQ). The implication is that the company uses the color-coding system for managing its priority concerning planning and execution. In addition, this system further aids visibility which is an integral part of DDMRP dynamics. In this regard, the color-coding system helps the company to determine if additional supply will be required based on the available stock position (Ptak and Smith, 2011).

![Diagram](image)

**Figure 16**: Inventory-Asset Liability Curve with buffer zones (Adopted from Ptak and Smith, 2011)

The accumulation of the green, yellow, and red zones will generate the highest buffer level or top of green (TOG). In order to determine the respective zones, certain rules must be applied with respect to determining a global attribute as against an individual part trait, as shown in Table 4 below. Table 4 illustrates the minimal amount of information needed to see zone sizes and thus buffer levels for
acquisition, manufactured, and allotted parts. Each zone inside the buffer (G, Y, or R) is sized by a formula of average daily usage (ADU) over a percentage of time intervals (denoted in days). The green zone also will have the choice of being expressed because the minimum order quantity (if present) when that minimum order quantity is critical, the yellow zone for all buffer profiles is sometimes set at 100% of usage over a time interval, and the red zone has two subzones. The summation of those two subzones will define the whole red zone quantity. One subzone is named red zone base while the opposite subzone is named red zone safety as. This is indicated in the Figure 17 below. The buffer level is calculated using equation 7 as indicated earlier in this section.

![Red Zone Base Red Zone Safety Yellow Green](image)

Figure 17: buffer zone with red zone base and red zone safety (Adopted from Ptak and Smith, 2011)

### Table 4: Determining Buffer Levels and Zones. Adopted from (Ptak and Smith, 2011).

<table>
<thead>
<tr>
<th>Group Attributes Inputs</th>
<th>Individual Part/Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Lead Time Concept</td>
<td>• Average Daily Usage</td>
</tr>
<tr>
<td>• Make, Buy, or Distributed</td>
<td>• Discrete Lead Time</td>
</tr>
<tr>
<td>• Variability Category</td>
<td>– ASR Lead Time</td>
</tr>
<tr>
<td>• Significant MOQ Factor</td>
<td>– Purchasing Lead Time</td>
</tr>
<tr>
<td></td>
<td>– Transportation Lead Time</td>
</tr>
<tr>
<td>• Ordering Policy</td>
<td>• Ordering Policy</td>
</tr>
<tr>
<td>• Location (Distributed Parts)</td>
<td>– Minimum</td>
</tr>
<tr>
<td></td>
<td>– Maximum</td>
</tr>
<tr>
<td></td>
<td>– Multiple</td>
</tr>
</tbody>
</table>

4.1.3 Dynamic buffer adjustment

Dynamic buffer levels permit the firms to adjust buffers to group and individual part attributes switch over time through various adjustments. Hence, as more or less variability is experienced as the firm’s strategy changes, these buffers conform or alter to fit the environment. Due to the continual increase of market volatility and complexity, it is expedient for the supply chain to adapt to these changes; the adaptability of the supply chain is enhanced by dynamic buffers in order for it to adapt to new requirements; hence DDMRP facilitates to stabilize the market fluctuations based on some functional parameter, market dynamics, planned or future events. The main purpose of this is to continually stabilize the inventory positioned with respect to maximizing return on capital employed (ROCE). And this can be achieved in three ways, which are the planned, recalculated and manual adjustment. (Pekarcikova et al., 2019)

- **Planned Adjustment**

  The planned adjustment is factored by strategic, historical, and business intelligence factors. It is characterized by the capability to manipulate the buffer equation to affect the inventory positions either by increasing or reducing the buffer levels and their respective zones at a certain point. The planned adjustment is utilized under the circumstances of seasonality and product ramp-up and ramp-down, which are caused by product introduction, deletion, and product transition (Ptak and Smith, 2011). The Planned Adjustment Factor is denoted with equation 8 below, and the buffer size is dependent on this equation.
ADU = ADU \times PAF(\%ADU) 

**Equation 8: Plan adjustment factor equation**

Where:

- **ADU** is the new buffer size
- **ADU** is the average daily usage.
- **PAF** is the plan adjustment factor. (Pekarcikova et al., 2019)

**Recalculated Adjustment**

The recalculated adjustment is based on an automated operation which is also factored by the capability of the planning system. It further disintegrated into two parts, which are the ADU-based adjustment and the zone occurrence base adjustment. The first instance, which is widely recommended, is based on a rolling horizon; the extent of this horizon in terms of dimension is user-defined and can be specific to its environment. Additionally, the length of the rolling time zone is dependent on the company, and it is also important to pinpoint that when the rolling horizon is too short, the buffer change becomes overreactive. When the rolling horizon is too long, the buffer change becomes underactive. Likewise, a zone-occurrence-based adjustment involves adjusting the buffers by measuring the number of defined occurrences within specified intervals. Most firms utilize this approach regarding the fixed time interval/reorder inventory model. However, this approach is not recommended due to specific challenges, such as the number of occurrences, the size of the interval, and the size of adjustment based on the number of occurrences. (Ptak and Smith, 2011)

**The Manual Adjustment**

This situation is triggered by alerts such as the ADU alert that aids visibility to changes not planned for in cases where the ADU calculations are inconsequential. These unplanned changes usually occur when there is some sort of miscommunication between the planning department and other departments. The ADU alert is designed to trigger warning signals to planners concerning a severe change in ADU over a shorter time frame than the rolling zone. (Ptak and Smith, 2011)

### 4.1.4 Demand Driven Planning

Demand-driven planning is characterized by generating supply orders such as purchase orders, production orders, and transfer orders in the precise amount and at the exact time. This DDMRP methodology component uses a net flow equation, referred to as an inventory equilibrium equation for buffer replacement that generates the supply order characteristic point in terms of time interval and quantity (Ptak and Smith, 2016). Also, at the decoupled points, equation 9 below gives each buffer’s net flow position, which is calculated daily.

\[
NFE = \frac{\text{Inventory at hand/stock} + \text{Expected Inventor-Qualified demand for demand/order}}{\text{Order Generation Time Interval}} 
\]

**Equation 9: The Net flow equation**

Pekarcikova et al. (2019) elaborated on this viewpoint, stating that order generation based on a clean flow is performed per stack. This calculation is what determines the NFP/Net flow position, which is recommended if there is a variation between the TOY orders from the NFP orders. DDMRP generates supply orders when the net flow position value gets into the refueling zone, which is the yellow color zone, and supply orders are made reaching the top of the green dimensions (Orue et al., 2021). DDMRP has five distinct planning categories. When appropriate, it will still have actively synchronized replenishment lead time (ASRLT) applied to them, namely replenished parts, replenished override parts, min-max parts, nonbuffered parts, and lead-time managed parts (Ptak and Smith, 2011).

**Replenished parts**

Replenished parts are the first section identified by Over top of green (OTOG), top of yellow (TOY), top of red (TOR), and stocked out (OUT), as shown in Figure 18 below. A color-coded buffer system strategically selects and manages these parts based on planning and execution.
Buffer positions are configured at regular time intervals when recalculated. Factors such as individual parts attributes and global elements are considered in determining the buffer level at this point. (Ptak and Smith, 2011)

- **Replenished override (RO) parts**
  These are the thoughtfully selected parts designated by the color-coded buffer system for planning and execution. These parts determine the inventory level within the planning environment and are said to be more stable than other replenished parts. In this situation, color coding enables planners to prioritize planning and execution activities in cases where the dynamic calculation of the buffer system cannot be determined using equations. Figure 18 below, as displayed, represents the conceptual rendering of replenish and replenish override buffers. (Ptak and Smith, 2011)

- **Min-max (MM) parts**
  Min-max (MM) identifies strategic parts that are less important or promptly available stockkeeping units (SKUs). The MM system can be otherwise referred to as a replenishment system that utilizes limited DDMRP tactics regarding order quantity. The "Min" represents the order point, while the "Max" represents the "order up to" inventory level. When max and min are calculated as a factor of average daily usage (ADU), Min-max buffers can be dynamically adjusted in the same way as replenished parts. (Ptak and Smith, 2011)

- **Nonbuffered (NB) parts**
  Nonbuffered (NB) is not stock-related but transfers made or procured to order or current orders made. The majority of parts fall into this category in most environments. (Ptak and Smith, 2011)

- **Lead-time-managed (LTM) parts**
  Lead-time-managed (LTM) parts required special care for the nonbuffered parts. In addition, these components are limited in quantity to require stocking and demanding to manage, particularly when the orders have long lead times, and the supplies are remotely sourced. (Ptak and Smith, 2011)

*Figure 18: Replenished and Replenished override part buffer idea (Adopted from Ptak and Smith, 2011)*
4.1.5 Visible and Collaborative Execution

This is the fifth part of DDMRP, which involves applying various types of alerts concerning the existence of dependent and independent decoupling points in the BOM. This phase prioritizes already open orders at different supply chain levels for procured items or items required for production (Pekarcikova et al., 2019). The Planning and execution process is two-phase distinguished by DDMRP. In the Planning phase, the NFP facilitates the recommendation of supply order generation, whereas the execution phase deals with the supply order management to have a proper flow; hence this phase emphasizes the execution part of DDMRP as to the prioritization. This aspect is facilitated by color-coded alerts that help identify the prioritized orders, making it easier for the system to pinpoint a critical situation requiring attention. By this, the company will depend on the due date and prioritize the actual orders according to the buffer status (Kortabarria et al., 2018). The implication is that a company can strategically place its supply order based on in-hand inventory rather than using due dates (Kortabarria et al., 2018). Figure 19 below shows the DDMRP execution alert, disintegrated into two categories. These are the buffer status alerts and the synchronization alerts. While buffer status alerts focus on the stocked parts or in-hand inventory, the synchronization alerts, on the other hand, focus on the non-stocked part (Ptak and Smith, 2011).

![Figure 19: DDMRP Alert type (Adopted from Ptak and Smith, 2016)](image_url)
5. Problem Analysis

This chapter elaborates on collecting various literature in preparation for further analysis. Furthermore, it examines how the research questions will be answered concerning it being used to solve the problems in order to fulfill the purpose of the study. The Research questions presented are further narrowed down to specifics as to how they will be utilized and why they are selected to fulfill the research purpose.

As suggested by the author, a theoretical proposition strategy is a fundamental research strategy for providing a base for scientific research. It is a method of building explanations from theories and hypotheses postulated from a scientific perspective. This allows the author to casually build up explanations during the analysis in a descriptive manner around the proposed hypothesis from various scientists and authors of DDMRP with regard to transforming supply chain management. It also enables the author to understand the relationship between research questions and how they fulfill the research purpose, thereby strengthening the validity of the research.

Based on the purpose of this study, several pieces of literature were comparatively consulted by the author concerning DDMRP being a transformative adaptive tool to transform the supply chain. In this quest, various research questions were raised to satisfy the purpose of the study. Regarding the sources used, Ptak and Smith (2011) are significant sources to which answers are provided to all other research questions. It serves the author as a foundation on which other sources take guidance.

RQ 1 is about DDMRP and its components; the author of this research wants to encapsulate various authors' views on why DDMRP is exemplary regarding planning and execution. In addition, the author also wants to capture the modalities used by DDMRP modalities and dynamics in tackling the various challenges within the supply chain, as stated in RQ2 and RQ3.

For RQ2 and RQ3, Ptak and Smith (2011), among other sources such as Gopal and Seth (2021), Miclo et al. (2019) and Miclo et al. (2016) will be used interrelatedly to elaborate on how DDMRP can handle supply chain disruption by tackling demand and supply variabilities. This will be done in view of the bullwhip effect and inventory management perspective. The author considered other perspectives related to the problem before attempting to answer RQ2 and RQ3, perspectives relating to the specific methods used by DDMRP to counter the challenges witnessed by the supply chain. This further explains the connection between RQ1, RQ2, and RQ3. Meanwhile, in answering the RQ2, a practical case will be considered as to other forms of disruption aside from bullwhip; this enables the author to investigate whether DDMRP can follow a similar pattern in solving similar problems.

In answering RQ3, the author further examined other related articles based on previous research by which several considerations were made with respect to various organizations that had implemented DDMRP practices along with the related result. Further examinations were carried out with respect to the way forward with DDMRP in the near future.

It is pertinent to emphasize the use of a theoretical proposition approach to cross-examine the various research questions to strengthen the research validity further, hence creating a base for future research as this will be done by reviewing the works of literature in regard to DDMRP having the attributes to counter the bullwhip effect and inventory problems.
6. Analysis

In this chapter, findings are discussed by using the research questions as a basis for comparison with the theoretical framework. Precisely, this is accomplished by using a theoretical proposition by which the selected works of literature are used interconnectedly.

6.1 What is DDMRP, its components and advantages?

To address this research question, the available research literature was carefully reviewed and analyzed. The information obtained from the literature has been presented in this section in three parts. The first part explains the conception of DDMRP and why it was created. It also explains the features and constituents of DDMRP. The second part explains DDMRP components more appropriately and their overall effect on the supply chain. The last part explains the advantage of its implementation concerning some selected manufacturing organizations that had implemented DDMRP with the resultant effect.

From the perspective of its conception, DDMRP was created as a more effective demand-driven resolution, poised to proffer solutions faced by the manufacturing environment, programmed, and designed to facilitate the availability of materials to be supplied directly for consumption all around the entire bill of materials (BOM). DDMRP achieves this through its innovative tactics and approaches in inventory management via material planning and integrated execution strategy. The primary purpose of using DDMRP is to enhance the supply chain, when used in an integrated manner, by eliminating the built-up disruptions within the supply chain. In addition, DDMRP utilizes technical approaches to sustaining the pull-based scheduling and execution methodology, such as lean and DBR, effectively in a more complicated manufacturing environment. (Ptak and Smith, 2011)

According to Ptak and Smith (2011), DDMRP’s approach manages the supply chain properly in that DDMRP, as a new strategy, was developed to control material flow. It was made to deal with fluctuation, change inventory levels, and improve customer service (Ptak and Smith, 2011). DDMRP makes it easier to plan material requirements while enhancing visibility and information flow. Various issues in planning material requirements and ensuring seamless supply chains have been experienced in more traditional supply chain management techniques (Azzamouri, 2021). A manufacturing strategy that emphasizes reducing lead times, adjusting to market requirements, and providing an agile response to demand includes DDMRP as a significant component (Ptak and Smith, 2016).

Looking at the constituted features, DDMRP was developed by combining elements of distribution requirement planning (DRP), just-in-time manufacturing (JIT), theory of constraints (TOC), six sigma, and material requirement planning (MRP) with novel features to develop an approach that focuses on cutting lead times in a supply chain. Planners in the manufacturing sectors used the aforementioned traditional method individually prior to the advent of DDMRP. However, several shortcomings were recorded based on their inability to withstand a complex environment. For example, MRP was built on the principle of push and promote, which later exhibited flaws such as persistent shortages and longer lead times. Since JIT is built on the lean principle, which views inventory as a waste, it tries eliminating inventory. Companies using the JIT technique drastically cut their stockpiles, which makes the supply chain brittle, stiff, and vulnerable to fluctuations in demand and supply. (Miclo et al., 2016)

It is important to note that DDMRP has absorbed and possesses the individual characteristics of the various planning approach mentioned above, such as JIT, Lean, and others. These attributes make DDMRP succeed as an absolute planning structure, enhancing the supply chain with respect to an effective material flow for production purposes.
Looking at DDMRP from the perspective of its effect on the supply chain, DDMRP can be used as an adaptive model to curb variability in the distribution dynamics of stocks which were based on a bimodal distribution model of inventory as illustrated in the diagram below. The purpose of implementing DDMRP is to transform from Figure 20 to Figure 21. As shown in Figure 20, there is a systematic nervousness that was a direct result of the bullwhip effect, ultimately resulting in perpetual demand and supply variability, as will be addressed in the next section below. Thus, DDMRP is aimed at curbing and counteracting bimodal inventory behavior by providing the right stocks on time and in the right quantity based on actual demand instead of pushing them. The essence of this transformation is to maintain an optimal level of inventory which could, in the long run, promote a smooth operational flow. (Pekarcikova et al., 2019)

![Figure 20: A Typical Bimodal inventory (Adopted from Ptak and smith, 2016)](image)

Furthermore, DDMRP stands peculiar from other methods based on the characteristic it possesses, as represented in Figure 22 below. The Figure illustrates other basic features of DDMRP. This shows the framework of DDMRP and how it operates to smoothen the flow of information and operations. The Figure explains how DDMRP is seated on two basic frames, first is the decoupling point, which portrays the difference between dependent and independent demand. The main aim of this is to maximize return on investment (ROI) in the supply chain. Next is the actual demand, which is determined from the strategically placed buffer providing the needed information.

![Figure 21: DDMRP strategic inventory re-alignment (Adopted from Ptak and smith, 2016)](image)
Regarding the components of DDMRP and as detailed in section 4, DDMRP based its modality and effectiveness on the five components. This component forms the foundation on which the DDMRP principle is built. The First component facilitates determining the decoupling points positioning in the supply chain, acting as variability absorbers. Components two and three address buffer management concerning its coping with demand and supply variabilities. These components consider the operating conditions, changes in operational procedures, unpredictable events, and the market dynamics. Components two and three functions under the protect dynamics, where the flow is initially protected with sized buffers before being adjusted dynamically according to the number of parameters. Components four and five functions under the pull dynamics, as shown in Table 5. Demand-driven planning is the fourth step, making planning the flow possible. It allows priorities to be determined and supply orders to be generated. The entire process is monitored at this point to create supply orders in convenient quantities and in relation to correct timings. And lastly, visible Collaborative execution is the final component that facilitates the management of the daily routine with regular problems. This component manages to flow with different alerts and prioritizes orders to ensure timely customer delivery. (Miclo et al., 2019)

Table 5: Demand-Driven Material Requirements Planning components (DDMRP)

<table>
<thead>
<tr>
<th>Position</th>
<th>Protect</th>
<th>Pull</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic Inventory Positioning</td>
<td>Buffer Profiles and Levels</td>
<td>Demand-Driven Planning</td>
</tr>
<tr>
<td></td>
<td>Dynamic Adjustments</td>
<td>Visible and Collaborative Execution</td>
</tr>
</tbody>
</table>
DDMRP has the advantage of optimizing the difference between planning and responsiveness; it can plan material while increasing market responsiveness effectively. DDMRP helps the manufacturing industry notice changing customer demand and accommodate planning and production while pulling from suppliers in real time. This helps stop ordering excess inventory and start maximizing profit. The DDMRP system is expected to change the manufacturing industry culture and work habits over time, giving the industry a sustainable advantage in the long run. There were also postulations that DDMRP, a major driving force, could change the dynamics in the manufacturing industry in this modern era and the nearest future regarding material planning, which affirms its competitive advantage when implemented over other companies yet to utilize it.

Furthermore, the enhanced responsiveness of DDMRP directly translates into improved customer service levels. Organizations can consistently meet customer expectations and deliver orders on time by aligning inventory levels with customer demand and reducing lead times. This reliability in customer service fosters customer loyalty, enhances customer satisfaction, and strengthens relationships with key stakeholders. Satisfied customers are more likely to return and recommend the organization to others, leading to increased market share and business growth. This also helps position the company in a favorable position regarding market competitiveness, prompting a better market adaptation. DDMRP’s enhanced responsiveness enables organizations to adapt to market shifts more effectively. Organizations can quickly align their production and distribution strategies with changing market conditions by closely monitoring demand signals and adjusting inventory buffers. This adaptability allows organizations to capture new market opportunities, respond to emerging trends, and effectively manage seasonality or promotions, ultimately gaining a competitive advantage.

The implementation of DDMRP in a manufacturing organization has recorded notable success in enhancing the supply chain through inventory management, as in the cases illustrated in Table 6 concerning some notable organizations that had implemented DDMRP as their planning approach and the effect it had on the company system. The results of these companies, illustrated in the table below, indicate DDMRP’s transformative capabilities by way of benefiting the company. Notable benefits such as lead time reduction and service level improvement, which could ultimately lead to increased profitability from the financial perspective, were among the performance measures highlighted as the effect after DDMRP implementation by the respective companies. These impacts of DDMRP implementation highlight the advantages it brings to the organization in the long run. (Miclo et al., 2019)

Furthermore, a practical case study involves the IFAMS security organization. This organization deals with the manufacture and suppliers of industrial safety products, such as security locks of various components and grades. The production process merchandise modification and distribution to their customers. Before DDMRP implementation, the company had a high inventory level, a longer lead time with raw materials, and a complex planning system. On implementing the DDMRP approach, the company witnessed a reduced inventory of over fifty percent, with it expedites eliminated. Reduced planning time and facilitated planning for workers were also observed in this scenario. (Ptak and Smith, 2016)
Table 6: Advantages recorded in implementing DDMRP (Modified from Miclo et al., 2019)

<table>
<thead>
<tr>
<th>COMPANY INFO</th>
<th>BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albea group</td>
<td>Multinational company with 1.4 billion USD from sales operating at 100% service level</td>
</tr>
<tr>
<td>ABEA Construction Chemicals</td>
<td>SA Company subsidiaries to French multinationals, Involved in manufacturing of coated chemicals for construction purposes</td>
</tr>
<tr>
<td>Michelin</td>
<td>A well renown French tire manufacturing company, implemented DDMRP in 2015</td>
</tr>
<tr>
<td>IFAM</td>
<td>A designing and manufacturing company specialized in security lock, implemented DDMRP in 2014</td>
</tr>
<tr>
<td>PZ Cussons</td>
<td>A multinational company, involved in the production of several products, started implementing DDMRP in 2013.</td>
</tr>
<tr>
<td>British Telecom</td>
<td>A Service provider involved in telecommunication and accessories such as mobile telephone, started implementing DDMRP in 2012</td>
</tr>
<tr>
<td>Product Tubulars</td>
<td>Seamless steel pipe production company with value worth 114 billion USD, started implementing DDMRP in 2014</td>
</tr>
</tbody>
</table>

6.2 How can DDMRP handle supply chain disruption?

Disruptions in the supply chain process refer to an unplanned event that leads to a disruption in the flow of goods and materials across the supply chain. These disruptions can result from several causes, such as environmental hazards (hurricanes, pandemics, and other natural disasters), poor communication links between all members of the supply chain, disruptions in information flow between players in the supply chain, strikes by workers/manufacturers, and other industrial accidents. (Macdonald and Corsi, 2013)

Managers need to note that disruptions in the supply chain can occur irrespective of the amount of time and effort devoted to ensuring a smooth and seamless supply chain process. This creates a constant challenge of looking for ways to continuously recover from a negative event that disrupted the supply chain (Zobel et al., 2012). Disruptions in a supply chain can be classified into external and internal disruptions. The external disruptions are independent of any of the parties involved in the supply chain, while the internal disruptions are caused by members of the supply chain (Nobanee et al., 2021). A core example of an internal disruption is the bullwhip effect that emanated from information visibility challenges created within the system, as described in the earlier section, which is a focal point of this study. External disruption could be likened to unforeseen circumstances and conditions, such as natural disasters and pandemics, that could alter the global manufacturing landscape by hindering the supply chain (Nobanee et al., 2021).

As highlighted in section 1.3, a greater part of the supply chain disruption is the bullwhip effect, which kills the flow of operation within the supply chain. This emanated from no proper visibility within the supply chain owing to the demand and supply variation from the constant perplexity and
complexity of global manufacturing, further forcing the supply orders to be perpetually out of alignment (Ptak and Smith, 2011). In such a case, there is a distortion of information, like a communication breach between the supply and the customer, regarding specific items being moved for production purposes, prompting further variability in the system (Gopal and Seth, 2012).

Looking from the perspective of the bullwhip effect implication on a well-structured supply chain shows its ability to destabilize the linear linkage between the customer and supplier, prompting further misalignment. The supply chain system, in reality, works from the viewpoint of connected interdependencies, likened to a webleike network with the said complex interdependencies, hence could be immensely affected due to these interdependencies being subjected to some variability, resulting in a cumulative effect such as the bullwhip effect. In such a situation, the inventory position tends to be affected by being converted from back orders to excess, which can be a factor in the miscommunication of supply orders due to transportation delays involving product transfers. (Ptak and Smith, 2011)

DDMRP arrests this situation using the strategy of decoupling, which is vital to the subject matter. The method alleviates the increased complexity by creating strategic decoupling points along the chain and sizing dynamic reservoirs that absorb the variability and volatility in demand. In order to accomplish this, the dependencies are decoupled such that the accumulated variations within the network will be dampened, which takes place at respective positions known as decoupling points. By doing so, the supply chain performance is then enhanced because the performance of a supply chain solely depends on the effect of these decoupling points. An effective strategy of these decoupling points is necessary for coherent inventory positioning, ultimately increasing the firm’s flexibility and adaptability to demand variations. At the same time, the company capital is maximized simultaneously. Decoupling refers to an attempt to create interdependence between supply and material use, which commonly represents providing inventory in between operations to counter fluctuations in the rate of production of supplying operations, eliminating the impending bottleneck that was supposed to occur because of this. Whereas a decoupling inventory refers to the amount of inventory held up between operations in a distribution network to create independence between processes, with the intention of disconnecting the rate of use from the rate of supply of these items. These activities occur at respective locations in the supply chain’s product structure or distribution network where inventory is placed to create independence between processes and entities known as decoupling points. This strategy dampens the bullwhip effect before the system is buffered to avoid further variability, as elaborated in the next section. (Ptak and Smith, 2011)

The below Figure 23 as shown below gives a clear picture on how it works.

Figure 23: The Strategy of decoupling (Own Source)
The above diagram portrays a visible illustration of how the process of decoupling works. Point A in the diagram shows how the bullwhip effect transcends throughout the distribution network by persistently increasing the demand and supply variability. However, when decoupled with buffers at some point, dampening and compressing the demand variability by cutting dependencies within the systems as indicated at point B. The following section in RQ3 explains how the variability is curtailed.

A similar approach is applied for handling external disruptions such as natural disasters and pandemics, whereby dependencies within the supply chain will be decoupled before being buffered up. In this case, DDMRP uses stock buffers to create a scenario in which supply and demand are independent. This allows managers and planners of organizations to make better decisions. DDMRP can reduce lead times and engage multiple suppliers in unforeseen circumstances, minimizing inventory and saving costs (Khojasteh and Sato, 2015). In DDMRP, inventory positions are used to determine the most suitable positions for inventory purposes. Implementing DDMRP helps to reduce lead times and inventory levels while providing optimal customer satisfaction. In unforeseen circumstances, the risk is reduced because DDMRP determines buffer points daily using the net flow equation elaborated in the previous section. The fluctuation of the buffers in a DDMRP system shows the impact of disruptions on the system (Miclo et al., 2016).

6.3 How can DDMRP handle Demand and supply variability?

To deal with occurring changes in the business environment, the DDMRP concept was derived from other concepts such as material requirement planning (MRP), distribution requirement planning (DRP), 6 Sigma, lean, TOC, as well as specific innovations (Miclo et al, 2016). The four main DDMRP variability sources are supply variability, demand variability, operational variability, and operation time variations. The DDMRP helps to salvage the indifferences in using MRP and in lean. Therefore, the variability in both demand and supply because inventory is well managed. This is shown through continuously improved Customer Service, lead time compression, and right-sizes Inventory (Ptak and Smith, 2011).

Ptak and Smith (2011) further discussed the need to counter demand and supply variabilities in the supply chain. Demand variability emanates from the persistent spike in demand due to the uncertainty in demand from the customer side. In contrast, supply variability can be birthed from disruption, which could ultimately delay materials for production. With these variabilities, the system becomes impregnated with nervousness creating a chaotic picture from the demand and supply side. These variabilities in demand and supply can be further classified into three classes and can be defined with respect to discrete parts or SKU numbers. This is shown in Table 7 below.

<table>
<thead>
<tr>
<th>Demand Variability</th>
<th>Supply variability</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Subjected to frequent spikes</td>
</tr>
<tr>
<td>Medium</td>
<td>Subjected to occasional spike</td>
</tr>
<tr>
<td>Low</td>
<td>Relatively stable demand</td>
</tr>
</tbody>
</table>

DDMRP tends to tackle these challenges using the buffer management system. This system entails the regular control and handling of buffer level, keeping the level to a sufficient amount to counter inconsistency, hence maintaining a smooth flow of operations. The sole purpose of utilizing DDMRP to counter these demand and supply variabilities is that it focuses on maintaining a smooth flow of operations with regard to handling any hindrance due to the shortage of excess stock needed for production purposes. This is usually carried out by simply identifying which specific items need consistent attention because such items if not taken care of, could pose a threat to the system in general, resulting in either stockout or overstock, after which the items are then buffered in the right
amount to ensure a constant check on their inventory level for replenishment orders to be placed at the right time. As discussed earlier in section 4.1.2, the buffer inventory consists of three zones regarding material planning. These zones represent the safety stock, mean-in-process replenishment quantity, and replenishment sizes, respectively, denoted in red, yellow, and green. Utilizing these zones facilitates the decision of buffer replenishment with respect to the inventory level. The same scenario is created in the execution context, where the stock buffers are also decomposed into the same three zones (red, yellow, and green) to emit alerts when the inventory is in the red zone or over the green zone. ASRLT, lead time features, and planned adjustment factors (PAF) are used in DDMRP to design buffer levels (Inventory or stock). Obtaining the ADU may result from first-time DDMRP implementation based on demand forecasting. According to DDMRP, ASRLT identifies the longest sequence unprotected in a bill of material while considering lead times. Implementing this idea for production can be said to be impactful as a planning ideology since it strategically identifies specific items and decouples the same items to the other part of the system such that the interdependencies refrain from inciting system nervousness. (Gopal and Seth, 2021)

A similar argument was further presented by Ptak and Smith (2011) regarding manufacturing parts, suggesting that the manufacturing parts are less subject to demand variability if the manufacturing items feed another level of the buffered component or end item. These parts are less subject to supply variability if they consume critical parts that are replenished strategically. This is due to the dampening nature of the buffer break walls.

Figure 24: Different variability factors for combination buffers (Adopted from Ptak and Smith, 2011)

Figure 24 above illustrates how the buffer manages the various demand and supply variabilities levels within the manufacturing process. This shows how the arrows from left to right represent supply variability, entering and exiting the buffer, on emerging from the buffer, have become smoother in the flow, indicating consistent availability. Conversely, arrows from the right represent demand variability, which enters in and comes out from the buffer to a smoother flow, indicating consistent order quantities at intervals.

Figure 25: Dampened Variability at different decoupling points (Adopted from Ptak and Smith, 2016)
In addition, Figure 25, as shown above, also represents stock buffers designed to facilitate the bi-directional dampening of variability poised to notably reduce or terminate the bullwhip effect. With this scenario, there is an understanding that stocks can remain independent from the supply when adequately planned, thereby cushioning products from disruption by dampening the variabilities from both the demand and supply sides. It is also essential to know that each buffer is ranked in a hierarchical colored zone for easy priority determination concerning planning and execution. In addition, the above diagram represents the core concept of supply order generation, with factors such as lead time compression, variability dampening, and placed buffers at decoupling points. (Ptak and Smith, 2016)

Furthermore, Miclo et al. (2016) illustrated this in their research with a case study of a company involved in manufacturing and producing different-size reducers composed of different parts. The purpose of using this is to further strengthen the viability and reliability of this research. The hypothesis formulated for the case study was to prove that DDMRP was a superior planning methodology as it can drastically counteract variabilities of all sorts and also within the buffer management. The review entails the production of different sizes of reducers and their spare parts, which convey different product types, are produced daily according to daily demand, and products are made to stock. On factoring all production parameters, such as setup and cycle times, with bottlenecks also considered, a simulation test using a discrete event simulation (DES) was then carried out for different scenarios and phases under separate conditions. A DES is a technique used by scientists and researchers in showcasing a real-world scenario, which can be disintegrated into a set of separate systematic processes with an ability to independently progress over time, with each specific event occurrence being assigned a logical time. Scientists, over time, have used this method to analyze and draw out findings from different research. This was carried out from two perspectives. The first scenario used the traditional planning method (MRP/MRPII) to fact-check these products' demand and supply variability. Therefore, the same test was run utilizing DDMRP principles, and both results were obtained and compared. The result from the case study proves the dominance of DDMRP in tackling and reducing demand and supply variabilities derived from various sources. This illustration, as per Miclo et al. (2016), further indicates that the result thus explains DDMRP's ability to develop properties that are recognized to pull flow management policies which were obtained at unstable demand.

6.4 What are the challenges and opportunities with DDMRP application in the manufacturing industries?

Implementing DDMRP in a manufacturing organization could serve as a credible advantage to the firm, in terms of competitiveness over others, by enhancing the company's supply chain in various forms. The advantageous offer by DDMRP is based on its characteristics in terms of combining different features and techniques in a consolidated supply chain. Hence, to maximize DDMRP's benefits and make the process more efficient, it is imperative that every link in the supply chain consolidates, collaborates, and shares all necessary and valuable information, which can be accomplished via cloud computing (Ptak and Smith, 2011). However, upon examining various literature on the DDMRP case study, it was discovered that DDMRP has had some limitations and drawbacks of its own. In a theoretical approach, DDMRP, in the real sense, is regarded as the future for planning and material management with a hybrid characteristic and an innovative idea that is not all exempted from challenges. One such challenge is the complexity of selecting a buffer position, which becomes increasingly difficult with BOM levels. Although, with the aid of decision-making tools, planners in the organization could be assisted in making crucial decisions with respect to the positions and level of buffers, and due dates, which could enhance the minimization of such challenges.
The second challenge with DDMRP is the practical adaptability of the company’s acceptance of this new standard based on DDMRP being a new concept with limited literature covering it, so further research is necessary. Because of this, most organizations still need to be convinced of DDMRP implementation and practice, hence sticking to the traditional planning method. Hence, implementing and applying the DDMRP strategy could be a significant challenge for some companies practicing conventional planning tactics.

Another constraint the DDMRP approach encounters is the complications involved in the planning-execution transition. Such complexity is spotted at the buffer levels and the order due dates at buffer positions. This is triggered based on variations between buffer positions and selected lead time data parts, which ultimately inhibit proper flow management by exhibiting an unsuitable order generation and stockout. For this reason, future research is necessary to determine how these variations can be curtailed to establish an efficient DDMRP application. This generally has some financial and cost implications for the manufacturing firm. In this regard, analysis is usually carried out to determine the position of buffers concerning return on investment (ROI) which can be determined from the associated cost of raw materials at their various positions. (Miclo et al., 2016)

Subsequently, other arguments have been presented, questioning the integrity of DDMRP concerning lead time reduction. According to De Kok (2017), while DDMRP has the potential to drastically reduce the lead time, which is profitable to the supply chain, the author argued that DDMRP cannot reduce all lead, citing the case of an overseas supply. For example, getting shipment between far regions such as China to the United States could require a fixed period of delivery time. Such situations can serve as a bottleneck to DDMRP implementation. Furthermore, DDMRP effectively determines where and how products should be stocked. Although one of the biggest arguments centered on its challenge is determining the number of products to be stocked, this could also affect the inventory level concerning the safety stock level.

However, there are opportunities for DDMR exploitations for planners in the near future. This allows scientists and future searchers to exploit the content of DDMRP further to be even more suitable than its current state. For example, some suggestions have been presented on how DDMRP can be combined with other planning methods to have a better and seamless result. One such is the suggestion of DDMRP being combined with a conWIP system. A Conwip system is defined as a constant work in -progress, which has to do with designating a control strategy that limits the total number of parts allowed into the system simultaneously. As soon as parts are released, they are processed as quickly as possible to end up in the last buffer of finished goods. Combining the ConWIP system with DDMRP may solve the DDMRP production order generation and priority management problems. Thus far, the system has received minimal attention, with just a few researches on factors and operation analysis or scrutiny of DDMRP performance against other methods in the manufacturing industry published in the literature, research papers, and academic curricula.

Another opportunity could be the need for further research into DDMRP, such as the demand to remove the lead time variation for parts in the selected buffer positions, as this can hinder the flow leading to overstock or stockouts. This explains the possibility of more discoveries in DDMRP regarding more findings and techniques used in handling variation.
7. Conclusion and Discussion

This chapter presents the conclusion and discussion of this research and will be followed by recommendations for future work.

7.1 Discussion

Due to the system complexity, supply chains in the manufacturing industries have evolved with different planning methodologies. Reforming the supply chain is essential because materials play a significant role in the production process, as there can be no production without materials. Material planning strategies changed over time to accommodate increased supply chain complexity, prompting system nervousness. This explains the transition from the traditional planning methodologies to DDMRP. (Gopal and Seth, 2021)

To examine the impact of DDMRP on supply chain management, a review of the advantages and success stories was elaborated in section 6.1 and table 6. This shows its significance in material planning since its inception. The impact of DDMRP on an organization was accessed and studied with a qualitative approach. As mentioned in the analysis section, improved flow and information patterns, increased service level, and reduced lead time were mainly the performance criteria obtained from our findings. This results in ultimately in greater operational efficiency and increased productivity for any organization implementing DDMRP.

Furthermore, customer and business satisfaction play a crucial role in the survival of any business. The findings align with those of Ptak and Smith (2016), who established DDMRP for material planning to enhance flow efficiency by compressing lead time and increasing service level. Brave (2011) elaborated on the relationship between lead time and customer satisfaction. As the lead time is reduced, customer satisfaction increases. The result from this study shows that DDMRP implementation can drastically reduce lead time generally in the supply chain, which fosters customer satisfaction, by creating a win-win situation for both the company and their client, thereby enhancing a good business relationship.

Discussing the entire concept of DDMRP is a vital part of this research. Manufacturing companies have great potential when using DDMRP approaches regarding material planning for production purposes. DDMRP has evolved over the past decade by building up its properties from the advantages of previous logic, such as MRP techniques and lean operating principle, forming a hybrid characteristic with other innovations (Miclo et al., 2019). DDMRP can constantly monitor the dynamic market situation, hence using innovative techniques which monitor the planning parameters to adapt to the dynamic market situation. Unlike traditional methodologies, DDMRP uses special features and attributes to monitor and control inventory. Part stock levels can be easily represented using this methodology since they can be depicted as colors coded which can easily be comprehended and does not require complex classification metrics for identifying parts. DDMRP is regarded as a better approach for planning methodology since it is the NFP which is based on actual demand, unlike forecast, which can be inaccurate for the most part. Using actual demands facilitates the optimal inventory, eliminating excessive and unwanted stocks or stock-outs. DDMRP utilizes ASLRT running through the entire bill of material. This enables the planners to determine more realistic replenishment dates, prompting proper visibility and enhanced control of system nervousness.

Furthermore, it is also important to elaborate on how DDMRP affects the system entirely in connection to its ability to transform the supply chain through inventory management, discussing how it first affects the inventory and then the supply chain in context. DDMRP facilitates the reduction of excess inventory, which can tie up valuable working capital, lead to carrying cost and obsolescence risks. The approach also reduces the reliance on long-term forecasts and focuses on
actual customer orders and demand signals. Organizations can avoid overproduction and excess inventory accumulation by aligning production and inventory levels with real-time demand. This proactive approach to inventory management reduces the risk of holding obsolete or slow-moving inventory, optimizing cash flow and improving overall financial performance. This, in turn, can improve cash flow. By reducing excess inventory and carrying costs, organizations free up working capital that can be reinvested in other business areas. The dynamic buffer adjustment feature ensures that inventory levels are aligned with actual demand, minimizing the need for excessive stock holdings. This optimization reduces the amount of capital tied up in inventory, improving liquidity and providing organizations with financial capabilities to re-invest in growth initiatives or respond to market opportunities.

On the other hand, the DDMRP approach has a tremendous effect on the supply chain in general by fostering collaboration among various stakeholders in the supply chain, including suppliers, manufacturers, and customers. By sharing real-time demand signals and inventory information, organizations can establish stronger partnerships and effectively align their activities to meet customer expectations. There are a variety of ways to accomplish this. One of such is through suppliers’ collaboration. With this, organizations can collaborate with suppliers to ensure timely replenishment and avoid supply disruptions by sharing real-time demand information and inventory levels. Supplier collaboration can include joint forecasting, vendor-managed inventory (VMI) programs, and collaborative production planning. This collaboration fosters stronger relationships, improves reliability in the supply chain, and reduces lead times, ultimately benefiting both organizations and end customers. This, in turn, can improve visibility within the system in the long run. DDMRP enhances supply chain visibility by providing stakeholders with a comprehensive view of inventory levels, demand patterns, and production schedules. This visibility allows organizations and their partners to gain insights into the overall supply chain performance, identify potential bottlenecks or inefficiencies, and take proactive measures to address them. Improved visibility enables better planning, risk mitigation, and responsiveness, fostering collaborative problem-solving and decision-making.

Conversely, the DDMRP approach has also been criticized based on some limitations observed by researchers and manufacturing planners. One of such criticism is DDMRP’s inefficiency in adjusting and managing variability sources in every part of the network, as the system can witness some difficulty in trying to model variations. There is also a challenge in execution concerning buffer management which is based on different levels of the status of individual parts and due dates. The entire rules set for this process could vary due to increased BOM complexity. The execution process could be strained due to the continuous increase in BOM complexity, which could fail in the DDMRP application process. With these challenges and criticisms comes the need for further research. Therefore, it is recommended for planners and scientists to further exploit DDMRP in the future to enhance its capabilities and effectiveness regarding material planning, which could be one way to generate more findings in regard to reducing the challenges.

7.2 Conclusion
Results from the previous chapter are analyzed and discussed in this chapter by bringing the study to a conclusion. An overview of the answers provided to the research question is presented in this chapter.

7.2.1 RQ1: what are DDMRP and its components?
This study gave insights into the operations of DDMRP with a significant explanation of its five components, features, characteristics, and the overall advantages it yields to the company when implemented. And also illustrates how DDMRP, when applied in supply chain planning, provides a more uncomplicated method of managing material flow by planning material requirements and
improving information flow. The research question was answered by conducting a comprehensive literature review.

The results from the analysis reveal the effectiveness of DDMRP as a superior planning approach over the previous traditional methodologies. The results further show the profitability of DDMRP when implemented, as illustrated by the various companies that choose to work with this approach. It affirms from both the scientific and company perspective that, DDMRP is mainly based on proper inventory alignment from a disorientated state, thereby improving its service level considerably, decreasing the lead time immensely, efficient demand and supply. The findings also affirm that DDMRP could be a standout to global competitiveness in the long run regarding material planning. Furthermore, the study shows that profitability and cost savings are the main drive toward DDMRP implementation.

7.2.2 RQ2: How can DDMRP handle supply chain disruption?
This thesis is mainly aimed at the Impact of DDMRP on supply chain disruption, explicitly targeting the bullwhip effect, which hindered the visibility of information flow within the supply chain. Likewise, this question was answered by extensively reviewing the pieces of literature on the subject matter.

The result derived illustrates how DDMRP utilizes a decoupling strategy to mitigate the bullwhip effect, thereby prompting proper visibility and information flow within the system, by so doing, averting further variability in demand and supply, which could be capital intensive for an organization. The result further explains the importance of isolating dependencies within the supply chain in order for operations to continue despite impending inhibiting factors fighting operational flow within the supply chain system.

7.2.3 RQ3: How can DDMRP handle supply and demand variability?
This study investigated the Impact of DDMRP on impending and successive variabilities from both supply and demand end, which emanate from the bullwhip effect amplification. Also, an extensive literature review was conducted in order to answer this question.

The result derived illustrates the importance of an adequate buffer management system, hence enhancing the flexibility of the supply chain process and maintaining the inventory, as too much stock in inventory can lead to the wastage of resources if variations occur. The result further explains how the buffer systems could dampen the amplified variability. It further shows that from a company and scientific perspective, this idea is critically centered on supply chain sustainability by optimizing inventory with regard to having the necessary and sufficient materials needed for production at the required time.

7.2.4 RQ4: What are the challenges and opportunities with DDMRP application in manufacturing industries?
This section identified specific challenges facing manufacturing companies in implementing DDMRP while also looking at the possible opportunities associated with DDMRP in the near future. By critically reviewing the relevant literature, some notable answers were then provided to the RQ.

The result highlighted some limitations witnessed after DDMRP, even though some immense benefits were witnessed also. The study further presented some future opportunities that could occur with DDMRP over time as it continues to evolve. One such is the suggestion of integrating DDMRP with other systems to facilitate a better result. These results derived further prove the necessity of future research.
Despite some limitations, these findings from the stated analysis prove the credibility of DDMRP. As analyzed, DDMRP had proven to be an added advantage for organizations implementing the approach regarding the effect on the company's service level and lead time compression. These attributes can be profitable for the organization in terms of finance. Also, from the findings, it can be concluded that DDMRP relies on decoupling and buffer management to clamp down supply chain disruption, thereby restraining demand and supply variability. Hence, utilizing the DDMRP methodology for material planning purposes could be a competitive edge over other companies with different approaches. For companies to be very confident in DDMRP implementation in the future, there is a need to assess the influence it could have on the organization after implementation. Overall, the effectual practicability of DDMRP needs to be tested to verify its credibility and efficiency amongst various industrial platforms, hence sustaining, revitalizing, and rebuilding the process.

In conclusion, DDMRP has been recognized in academia and the industrial world as an exceptional planning and execution system strategized to fulfill the requirement for a dynamic manufacturing environment by enhancing the flow of operations. This research entails an in-depth review of the literature available in academia with the necessary and relevant facts pertaining to DDMRP, supported by a related case study about DDMRP practice. However, this study does not consider the empirical implementation of the subject matter. Therefore, all facts and findings are based on theoretical discoveries and conclusions. Furthermore, this thesis can serve as a foundation for further studies and provide the platform for industrial applications regarding DDMRP implementation.

7.3 Future Research

Despite fulfilling the research purposes of transforming supply chain through inventory management using DDMRP, some findings present the imperfections of DDMRP. One of such findings are the company's unwillingness to adopt this method based on the limited amount of literature and research on DDMRP because of it being a new concept. However, this makes it also necessary for future research to look more into the core subject, as new findings about DDMRP will likely unfold as it continues to evolve.

The limitations mentioned above, as highlighted in this research, pave the way and gives the foundation for future research. Firstly, it will be interesting for future researchers to explore more literature and different companies implementing DDMRP to fact-check with companies' data and parameters regarding simulations, companies' results, and analysis. This thesis identifies the potential of DDMRP synchronizing with other planning methodologies and techniques, such as ConWip. Hence further research on this must also be carried out. Another viewpoint for future research could be the impact of DDMRP on resource sustainability concerning material used for production purposes.

7.4 Sustainability

The concept of sustainability is usually viewed from three perspectives: economic viability, environmental protection, and social equity. These are otherwise known to be the three pillars of sustainability, linking social and human development, economics and profitability, and the environment (Morelli, 2011). Proposals from the social perspective could have little or no effect on an organization regarding material planning, as implementing the DDMRP strategy may further prompt the organization to hire more people for planning purposes. The economic perspective suggests a cost-saving approach which indicates that an organization can make money from the innovative planning strategy, with respect to DDMRP being used as a model to cut down abnormalities such as the aforementioned bullwhip effect and the unbalanced inventory nature. With this factor addressed by DDMRP, the inventory systems become balanced, thereby increasing improving the service level by saving costs which is a result of eliminating inventory capital tied up. Changes suggested from the environmental perspective with respect to material planning have less
impact on an organization. However, implementing DDMRP as planning activities for profitability is the core focal point of any company, which could also keep the mindset of environmental sustainability in view.
Reference List


