TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING
Department of Mechanical and Industrial Engineering

ROBOTIC PROCESS AUTOMATION IN SUPPLY CHAIN OF READY-MADE GARMENT INDUSTRY: CASE STUDY ON THE EXAMPLE OF VIYELLATEX LTD

ROBOTPROTSESSIDE AUTOMATISEERIMINE VALMISRÕIVATÖÖSTUSE TARNEAHELAS VLTELLATEX LTD NÄITEL.

MASTER THESIS

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AUTHOR'S DECLARATION

Hereby I declare that I have written this master's thesis independently.

No academic degree has been awarded based on this study.

All data works, and major points of view used in this thesis from other author's work, have been referenced.

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1. Robotic process automation in the supply chain of the ready-made garment industry: a case study on the example of VITELLATEX LTD

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Eduard Ševtšenko

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Department of Mechanical and Industrial Engineering

MASTER THESIS TASK

Student: **Mohammad Enamul Karim (177270 MARM)**

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The study program, main speciality: MSc. in Industrial Engineering and Management

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Supervisor: **Eduard Ševtšenko** (Tallinn University of Technology)
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Thesis topic

English: Robotic process automation in the supply chain of the ready-made garment industry: a case study on the example of VITELLATEX LTD

Estonian: Robotprotsesside automatiseerimine valmisrõivatööstuse tarneahelas Vltellatex LTD näitel.

Thesis main objectives:

1. To Identifying which areas of the supply chain in the RMG sector of Bangladesh are managed manually and if there is the possibility to automate them.

2. How to automate previously identified areas of the supply chain in the RMG sector of Bangladesh by removing human intervention to make them accurate and efficient.

Thesis tasks and schedule:

NO	Task Description	Completion date
1	What are the potential steps of the supply chain of the ready-made garment industry of Bangladesh and How they are handled	August, 2020
2	The investigation was carried out to figure out the current way of supply chain handling and what robotic process automation has to offer i.e. literature.	September, 2020
3	Simulation is carried out based on current operations to identify bottlenecks, specially, steps that are handled manually in the supply chain and production process of Viyellatex Ltd.	October, 2020
4	Simulation carried out replacing manual or semi-automated steps with robotic automation which appeared as bottlenecks, analysed results and recommended solutions to Viyellatex Ltd.	November, 2020

Additional data and requirements: ….…….....

Language: English……..

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Preface

I am solely grateful to those who's encouragement, advice and criticism extremely benefited this work which includes the following but not limiting.

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I am grateful to all my teachers, employees, and everyone who belongs to the Department of Industrial Engineering and Management to provide me with all types of resources and facilities to complete my thesis. Thank you!

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Eventually, to my beloved family members, thanks for your support, love, and understanding of the situation while I was both working and researching. Special thanks to my mom, my younger sister, elder sister, my niece and nephews for their inspiration. Special thanks to my elder brother *Dr. Monzurul Karim* to help me throughout my journey to Estonia. Finally, this dissertation is dedicated to the workers of the ready-made garment industry for their dedication, devotion, and hardworking to keep our economy moving forward.

List of abbreviations

RMG	- (Ready Made Garment)
SCM	- (Supply Chain Management)
RPA	- (Robotic Process Automation)
AI	- (Artificial Intelligence)
RDD	- (Requested Date of Delivery)
RFS	- (Ready for Shipment)
TP	- (Transport Planner)
RFID	- (Radio Frequency Identification)
MLC	- (Master Letter of Credit)
BBL/C	- (Back to Back Letter of Credit)
ML	- (Machine Learning)
EPC	- Event-driven Process Chain

CHAPTER 1 - INTRODUCTION AND PROBLEM STATEMENT

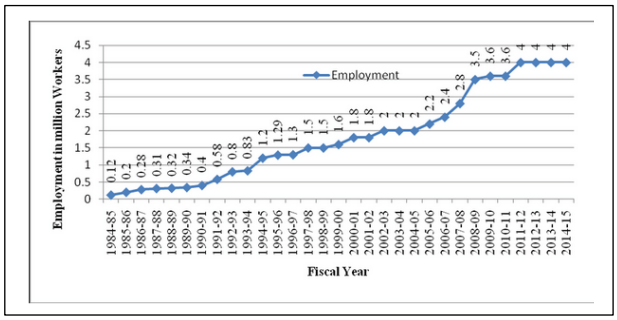
This section will emphasize the background study of the subject matter, economic impact, and problem of the thesis. Later, problems in the supply chain management of the ready-made garment industry in Bangladesh caused by inefficient manual management will be followed by the purpose of the study, and the research question winds up with limitations.

The RMG sector has a significant potential to contribute to the national economy through employment creation and poverty reduction compared to any other sector in the least developed countries like Bangladesh [21]. Simultaneously, the sector is facing new challenges which can be the determining factors of its future sustainability. Bangladesh a small highly populated country in Southeast Asia is an emerging economy in the world. RMG as a top ambassador of Bangladesh is familiarizing the country and its apparels all over the world. Since late 1970 this section has been the main contributor to the GDP and the major employment providers to the poor illiterate workforce. In terms of apparel export, the Bangladeshi RMG sector now has become a flagship brand to the developed countries as the European Union countries, the USA, and other parts of the world [23]. Despite all the achievements, still, Bangladeshi RMG section has many scopes of improvement in many areas such as supply chain and logistics, finance and export, demand and inventory management, finally in total integration of the ERP system. Although, Bangladesh has minimum wage competitiveness, but RMG sector has not been able to utilize this advantage to win work orders and deliver them in time due to unautomated SCM management [22]. Manufacturers are not concern about automation since they are getting enough employees at a cheap wage for manual management of the supply chain. Consequently, this has not been possible for employees to carry out a huge volume of repetitive task and report to the corresponding department continuously. As a result, If some routine and non-creative tasks of SCM could be automated by robotic process automation with artificial intelligence, it would be much easier to improve customer responsiveness, escalate flexibility for changing market conditions, boost customer service and satisfaction, enhance customer retention that leads towards effecting marketing. Automating supply chain operation does not mean workers will be replaced by the machines, they will learn new skills and move into more specialized roles instead [21]. However, old employees are retiring, new job vacancies are being created but youngsters are not willing to take those places due to lower salary and boring job roles. These job vacancies could be filled with RPA bots and those roles could be made more accurate, rapid, and efficient.

1.1 Background

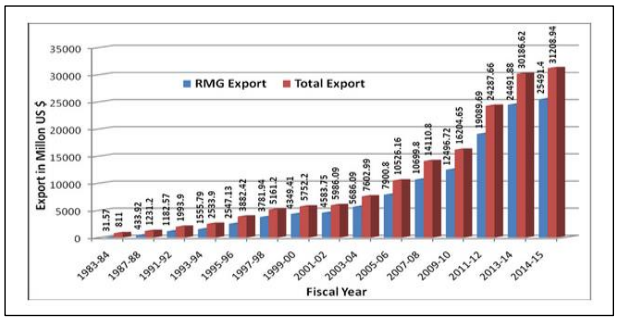
The world has been experiencing a more open and competitive economy than a nation-based economy since the beginning of the twentieth century as a contribution to technological advancement and globalization. According to (Hirst et Al, 2015) "globalization has a great influence on organizations to satisfy customer needs providing them with quality products and services at low cost". Several trade agreements were the important factors for that chasing for cheap labour and low-price solution persuaded industries to move from west to least developed countries. The population as well as socio-economic growth is peaked compared in any given time. People are fashion concern and try to keep pace with the current style of clothes which persuade them to buy more, consequently, huge demand for clothes are being created by 7.8 billion people that eventually cannot be produced. [18]

How the increasing demand of RMG is influencing the total economy if Bangladesh is shown as below



Year	Export of RMG (in million US$)	Total export of Bangladesh (in million US$)	% of RMG's to total expo
2005-06	7900.80	10526.16	75.06
2006-07	9211.23	12177.86	75.64
2007-08	10699.80	14110.80	75.83
2008-09	12347.77	15565.19	79.33
2009-10	12496.72	16204.65	77.12
2010-11	17914.46	22924.38	78.15
2011-12	19089.69	24287.66	78.60
2012-13	21515.73	27027.36	79.61
2013-14	24491.88	30186.62	81.13
2014-15	25491.40	31208.94	81.68

Source: BGMEA Website (Modified by the Researcher)



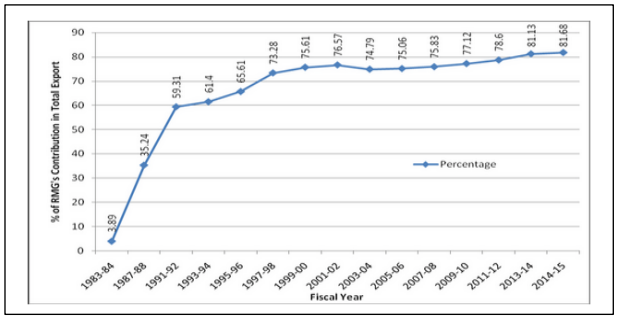


Figure 1. 1: Increasing demand for cloth wears and its impact on the economy [20]

The increase could have been even more if the Bangladeshi RMG sector had the capability to shorten the lead time. The inability of lead time management is caused by manual management of the supply chain is proved by many kinds of research. Robotic process automation in SCM could make the RMG sector more consistent and efficient [24].

Robotic process automation (RPA) enables companies to automate daily tasks and carryout using the existing application system just like they were being completed by the employees as before. RPA performs using existing IT infrastructure without being required to integrate with any complex system. Consequently, RPA can be applied to automate back-office processing, workflow infrastructure, and process which are labour-intensive. RPA software is known as bots which liaison with the organization's internal software, user portal, website, to get a holistic scenario to carry out the process. Users can easily use this software on their laptop, desktop even on mobile devices. The main objective of the RPA process is to reduce repetitive and boring

tasks and enable the human brain to utilize creative tasks. The mentionable benefit of RPA is it does not require coding neither access to the application or code database. In the overall supply chain process, RPA is still in its infancy stage, specifically in the RMG industry, even experimenting is not taking place since most of the RMG industry is in the least developed countries, therefore, manufacturers are still not considering this to be a better option. However, industries that have included automation in their supply chains are experiencing a lean and efficient effect on their supply chain. Although it was challenging at the beginning, because, most of the manufacturing companies depends on RFID (Radio Frequency Identification), ERP (Enterprise Resource Planning), CRM (Customer Relationship Management), etc. Consequently, RPA was not flexible enough to incorporate all these complex and continuously changing patterns of the supply chain. But for now, it is possible to remove manual intervention by including intelligent bots with machine learning capabilities that enable RPA to have cognitive abilities to input as humans to manage SCM to a great extent. [27]

RMG industry is labour intensive as most of the processes are handled manually which results in the inefficient and delayed output. For the least developed countries, this is the most important business sector, because most of the resources of that country are used in this sector. Since this thesis is based on the Bangladeshi RMG industry, therefore, Supply chain of the Bangladeshi RMG industry is studied here. It has been found that cheap wages and raw materials are the main advantages, but lead-time management is the main challenge there. If some of the manual processes in the supply chain, demand planning, warehouse management, purchasing, invoicing, and logistics management could be automated, lead time management would be in a better position. Likewise, it would help in reducing inventories, operation cost can also be lessened, cycle time will be compressed, end up with enhancement in asset productivity and the company's responsiveness to the market. As we intend to apply robotic process automation with artificial intelligence on the existing operation, continuous progress and development are expected to be observed in the long run. [22]

1.2 Problem discussion in Bangladesh case

The Supply Chain of the Bangladesh RMG industry is like a chain system made of rings. The chain is strong when all rings are strong, the chain is weak even a single ring is weak. Although the Bangladeshi RMG sector is enjoying price competitiveness due to the lowest wage amongst its competitors. But they are far behind in lead time competition comparing to the competitor countries. The following are the potential causes that make RMG SCM inefficient, which could be improved by applying RPA [19].

Why the RMG industry of Bangladesh cannot keep its production pace along with the increasing demand, persuading many firms to leave many potential work orders due to inability of delivering them on the Requested Date of Delivery [19].

Lead time (LT)

From the date, a work order is received up to the date to handover the forwarder for shipment is known as Lead time. LT is significantly important in the RMG industry because fashion is designed based on the season, therefore, clothes designed in summer will not be sold in winter as well as in spring. As buyers already invested a lot of money, they do not afford to extend the LT. As a result, to keep the LT, manufacturers design a critical path to accomplish the production work within the time, as we know every work has a schedule. Usually, for woven garment order buyers allow 60-90 days, since required raw materials are imported, as for knit garment, the LT is 30-60 days because raw materials are locally procured. If LT cannot be kept, producers have three options to cover the loss. Firstly, shipping by the air bearing the cost by the manufacturer. Secondly, shipping by the sea at a discount. Thirdly cancellation of shipment which manufacturers cannot afford, as they import raw materials based on back-to-back LC which means they must pay raw material importing cost with the foreign currency. Hence, discrepancy or hindrance in small parts can jeopardize the whole shipment. The main issue which affects the LT most is sourcing different parts from different suppliers. The main items are needed for a shirt are listed in the below table. [20]

Product	Items		
Men's Woven Shirt	Main	Sewing	Finishing
	Fabric	Thread Button Interlining Main label Fit label Size label Care label Barcode label Zipper Elastic	Pin, Poly, Carton, Plastic clip, M-Clip, Butterfly, Neck board, Backboard, Collar insert, Collar bone, Poly sticker, Tag pin, Carton sticker, Price ticket, Tie (if needed)

Table 1. 1: Main accessories used in apparel production [19]

Improper demand planning and inventory tracking

In the Bangladeshi RMG industry, due to improper demand planning, either surplus inventory occupies the warehouse leaving inadequate space for finished goods or a shortage of inventory to carry out production. Moreover, purchasers are not aware of how when and how much inventory to purchase. In addition to that missing inventories or outdated inventories are not track properly to acknowledge the store clerk about that. RMG products are as much critical as a whole shipment can be cancelled due to the missing of a tinny hangtag. [19]

The manual purchase process of raw materials from multiple vendors

A factory deals with 20 buyers who usually must source raw materials from at least 150 suppliers. Still in Bangladeshi RMG sector purchasing is done by a typical method which requires many employees and repetitive task which is as follows.

Consequently, processing documentation and managing the whole purchasing procedure manually requires many employees and most importantly many working hours which makes all required raw materials not arrive on time at the production area. [22]

Manual invoice management process delay supplier's payment

Procuring raw materials is a continuous rollout process depending on regular payment against suppliers' invoices. Getting paid is equally important for suppliers as well as RMG manufacturers. Garment accessories suppliers supply raw materials based on the payment of invoice of the last delivery, as they also need to pay for their production. Therefore, it is very important to process all invoice related tasks quickly to pay suppliers as soon as possible. Since invoice management is not automated it takes much more time to even make invoices ready for approval. Employees do all the tasks manually starting from printing out hard copies of invoices, that follow data entry, storing them in specific storage, and transferring them to the relevant departments for approval. [20]

Lengthy manual transportation management process:

As we know that RMG firms are located mostly in the least developed countries, therefore, transportation is greatly affected by political unrest, strikes, traffic congestion, road repair as alternative roads are limited. As a result, transport planners are required to optimize loading and transport scheduling. As transportation is manually maintained, dispatchers waste their time in many unnecessary lengthy steps such as, printing emails, logging in to transportation websites to find available loads, entering all load details, and finally retyping all the details to confirm loading which consumes around 20 hours of dispatchers time. [20]

1.3 Purpose of the Study

The study intends to identify potential areas of supply chain operations and ways of managing them in the RMG sector of Bangladesh. To assess the impacts of manually managed steps of SCM in overall efficiency and accuracy from a holistic point of view. Likewise, how many steps have scope to automate, the procedure to automation, and how much accuracy and efficiency could be achieved through automation. Precisely, to identify what types of autoboots could best suit in which areas of SCM. Eventually, the study attempts to incorporate all prospective steps of SCM into robotic process automation to reduce all types of waste, to increase efficiency and accuracy. [9]

1.4 Research questions

Research Question 1: Identifying which areas of the supply chain in the RMG sector of Bangladesh are managed manually and if there is the possibility to automate them.

Research Question 2: How to automate previously identified areas of the supply chain in the RMG sector of Bangladesh by removing human intervention to make them accurate and efficient

1.5 Limitations

To understand the thorough supply chain management process, the author required have a wide range of respondents working in the supply chain department of different RMG firms but ended with insufficient numbers of respondents due to confidentiality issues and reluctance to respond to survey questionnaires. Interviewing people from distance is a limitation since the schedule does not always match, needs cannot be fully conveyed, it is hard to keep people on correct track through an online interview. As the concept of Robotic Process Automation in Supply Chain Management in the RMG sector is not that popular, people cannot identify which areas of their operation are automated, what types of automation are those, and what types of automation is required. Finally, we are familiar with some standard steps of SCM but in many RMG firms, the steps are unknown, hard to relate with the standard ways of SCM management. Consequently, respondents were not able to relate their SCM activities with the SCM activities on the survey questions which resulted in digressed responses.

1.6 Company overview

Viyellatex and their operation

This study is based on the case study of supply chain operations of Viyellatex Ltd. Simulation was done based on the cycle time, cost, and different steps are being performed in Viyellatex ltd. Therefore, some precise gloss over on the company is as below to understand its operations [29].

A concise overview of the company

VIYELLATEX LTD is one of the most renowned and established knit and woven composite industries of Bangladesh located in the industrial area of Gazipur. It is a group of companies having other sister concerns as Youngone's Fashion Ltd, Viyella spinning, Viyella knitting, and dyeing. Viyellatex Ltd counts only on quality as it strongly believes that quality is the only fact why many famous brands have been satisfied with their product for ages. The company is not only providing quality products to world-famous brands but also contributing to the national economy by providing jobs to thousands of people and providing value to the resources it has been using [29].

Below is the company and its operations briefly.

Tittles	**Brief descriptions**
1. Name of the Company:	VIYELLATEX GROUP
2. Status:	Private Ltd. Company
3. Type:	100% Export oriented composite knit Dyeing Industry
4. Year of establishment:	2001
5. Year of starting production:	2002
6. Address	
Factory:	297, Khortoil, Tongi, Gazipur- 1712
Head office:	297, Khortoil, Tongi, Gazipur- 1712
	Tel. No. 8819281-2, Fax No. 880-2-8810445
	E-mail: viyellatex@youngonesgroup.com
7. Chairman & CEO	Mr. Rezaul Hasnat
	100% cotton,
	100% polyester
	a) Spun
	b) Filament
	Nylon
	Chief Value Cotton (CVC)
	Polyester Cotton blend
	Gray mélange (15% Viscose 85% cotton

	10% Viscose 90% cotton
	30% Viscose 70% cotton)
	Ash mélange (1% Viscose 99% cotton)
8. Production Capacity	
a) Knitting section	9 Ton per day (Body fabric)
b) Dyeing Section	14-15 Ton per day
c) Garments Section	18 million pieces per year
12. Different Departments:	a) KNITTING SECTION:
	• Knitting
	• Inspection
	b) DYEING SECTION:
	• Batch section
	• Dye house
	• Dyeing lab.
	• Quality control
	• Finishing
	c) GARMENTS SECTION:
	• Merchandising
	• Sample
	d) MAINTENANCE SECTION:
	• Electrical
	• Mechanical
	e) STORE SECTION
13. Total Manpower:	
a) Knitting section	250
b) Dyeing Section	Dyeing- 300 Finishing- 250
b) Dyeing Section	14-15 Ton per day
c) Garments Section	18 million pieces per year
c) Garments Section	3200
14. Major customers:	a) Marks & Spencer
	b) S. Oliver
	c) ESPRIT
	d) Tesco
	e) Puma
	g) GAP
	h) G.Star

	i) Wool worths
	j) TU

Table 1. 2: Overview of Viyellatex Ltd [30]

Brief gloss over in different sections of Viyellatex

There are mainly four operational areas in Viyellatex which are as follows.

b) Knitting section

c) Dyeing section

d) Garments section

e) Maintenance section

Main activities of Knitting section are as below

Activity Name	Machines are used to execute
Cloth Inspection: to check if there is any flaw in inhouse fabric	Type: Automatic Flat knitting machine Manufacturer name: Precision Fukuhara Works Ltd. Country: Japan Model No. M-100 Gauge G14
Circular Knitting: around 20 circular knitting machines produce the main body part of the apparel. Machines are different in specifications, number of cylinders, number of needles, number of feeders.	Machine type: Single jersey Brand: Fukuhara (vxc-3s) Origin: Kobe, Japan Machine dia &Gauge: 30”; 24G Extra cylinder: 30”; 20G No of the needle: 1860 No of feeder: 90

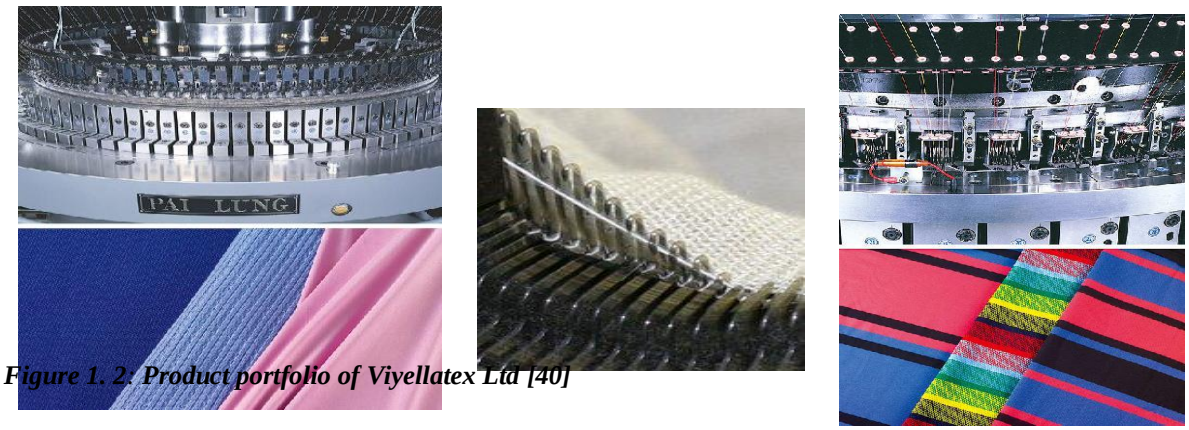
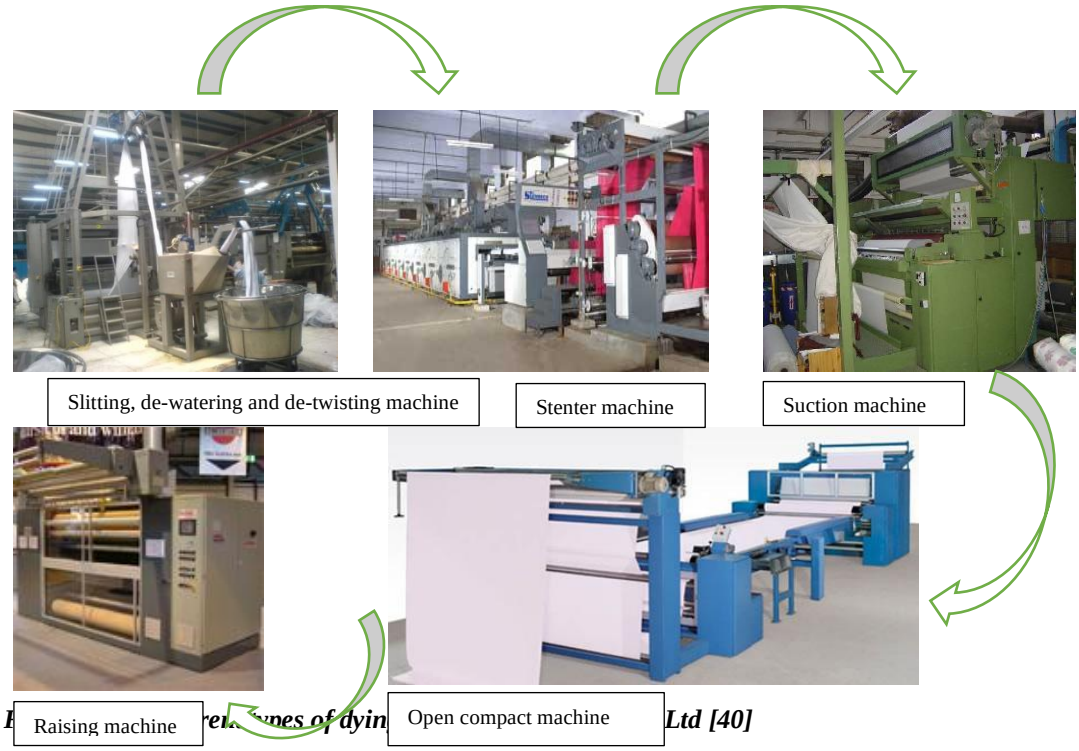


Figure 1. 2: Product portfolio of Viyellatex Ltd [40]

Main activities of Dyeing section:

Dyeing with chosen colour in the dying machine. The next step is slitting dewatering and de-twisting. Thread suction and stenter machines are used to straighten and remove loose threads. Raising is done with raising machine and clothes are compacted with an open compactor.



F rer nes of dyin Ltd [40]

Quality checking criteria

As I have discussed in the following chapter about quality check in different steps, therefore I would like to explain precisely the quality criteria. if the below problems are found in any apparel it is considered as rejected and is sent to the relevant department to fix the problem. They are as below:

Needle mark	Contamination & fly
Stripe	Slubs
Barre mark	Mixed yarn
Pinholes	Wrong design
Dirt stain	Holes
Oil line	Sinker mark
Uneven tension	Birdseye
Thick thin place	Oil line stain.

Table 1. 3: Quality checking criterion of Viyellatex Ltd [30]

CHAPTER 2 - LITERATURE REVIEW

2.1 Concise gloss over on supply chain management (SCM)

Precisely it is a dynamic management system to manage all supply chain activities and subsequent relationships to maximize customer value and attain a sustainable competitive advantage. SCM is also referred to as a demand chain management system which is the dynamic management of subsequent demand chain activities and relations to maximize customer value and achieve sustainable competitive advantage.

Managing the Supply chain efficiently has been an important concern for centuries, below are the definitions of how scholars have perceived SCM during this long journey. [1]

How the supply chain management concept changed and grow up during decades

Oliver and Webber (1982) stated that SCM is the process of planning, controlling, and implementing each step of supply chain operation that includes all spans of supply chain movement, storage of raw materials, starting from the point of origin to the point of consumption as efficiently as possible to attain customer satisfaction. [5]

Tan, Kannan, and Handfield (1998) specified that SCM which includes all process necessary to turn raw materials into the finished product, allowing them to recycle or reuse using supplier's capacity and technology to enhance competitive advantages. [5]

Bowersox, Closs, and Cooper (2002) define SCM which is sometimes called as value or demand chain get leverage from cleaver positioning of strategies to enhance operating efficiency. [5]

Sweeney (2007) explained that being in a company and traditional business, SCM attains long term performance for that individual company by systematic and strategic coordination. [5]

Wisner, Tan, and Leong (2012) stated that SCM is the consolidation of the key business process of trading partners which starts from initial raw derivation to the final stage or end customer that encompasses all subsequent processing, transportation, and storage facilities until final sale to the customer. [5]

2.2 Supply Chain in the Bangladeshi RMG Industry

For both the manufacturing and service industry, the SCM process starts with suppliers and end with consumers. In manufacturing, it starts with raw material suppliers, producers, distributors, wholesalers, retailers which ends with final customers and in the service industry it is suppliers, service providers, customers, and finally consumers. Therefore, for both the industries, customer satisfaction is the bottom line, precisely, the primary purpose of the existence of SCM. Likewise, the basic model of the Bangladeshi readymade garment industry includes suppliers, producers, ultimate buyers, and finally the service providers. Below is the very basic diagram of the SCM of Bangladeshi RMG.

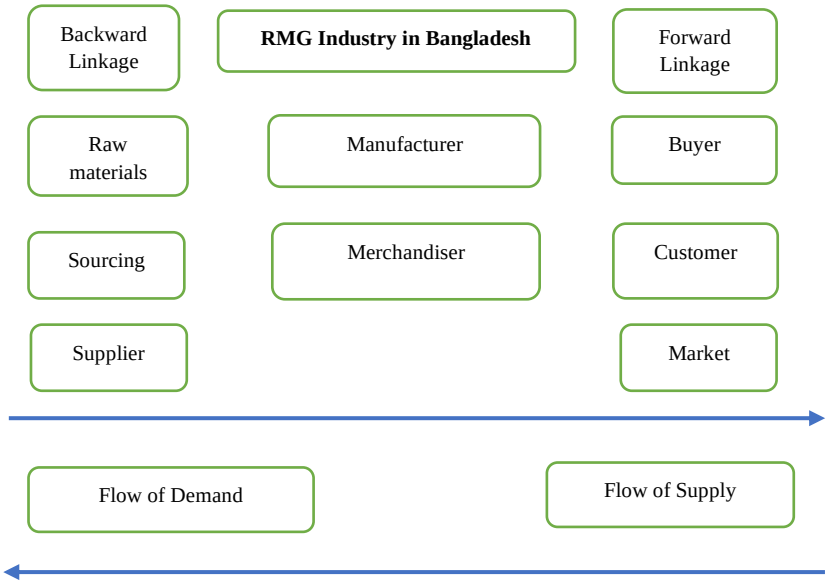


***Figure 2. 1**: **Basic SCM flow of Bangladeshi RMG Industry** [22]*

Three decision level:

Making a supply chain efficient requires assessing a product, flow of information, and funds. In the Bangladeshi RMG industry, the decision phase is divided into three categories based on the time frame as the frequency of each decision is highly influenced by the time frame.

Decision phases are as follows

Strategic Level: strategic level decisions are taken by the chairman and board of directors, which usually includes long-term goals, general directions, values, and philosophies. Strategic decisions are least structured driven by imagination, therefore, most risky [23].

Planning Level: Planning level decisions are taken by the head of the operation, SCM, merchandising. This type of decision helps to support, implement, and guide strategic decisions towards success. At this level detailed and reliable information is available. Medium important and medium-range decisions produce medium outcomes. Quick response and sudden change are the main advantages of this level, for instance, prioritizing orders and obeying commitments made at the strategic level [23].

Operation Level: Operation-related decisions are taken by line managers, supervisors, and workers at this level. The decision regarding replenishment, individual order, prioritization of important orders. Shipment route types such as by sea or air are based on the importance of order [23].

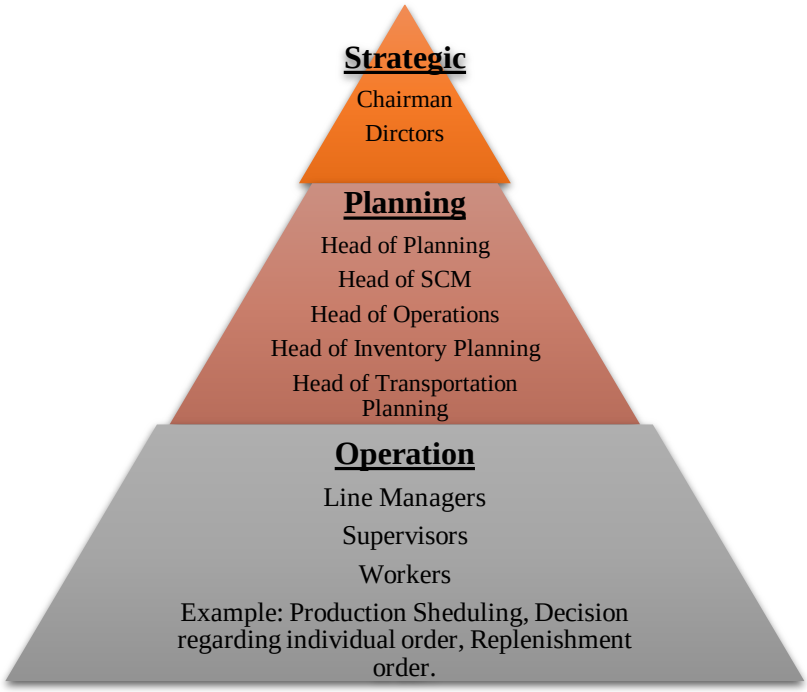


Figure 2. 2: Decision levels in SCM in RMG sector of Bangladesh [20]

2.3 Production process in Garment Manufacturing

From order receiving to shipment dispatching, almost a similar number of processes are followed in the readymade garment manufacturing industry of Bangladesh. How materials are moved throughout different processes until they are transformed into desired products is shown as a flow chart. This is to consider that the basic flow chart may differ based on production facilities and types of products. I try to portray a generalized production process followed by most of the RMG farms. To make it easy to follow the garment manufacturing process is categorized into pre-production, basic production, and post-production process [4].

Pre-production process

In this process, RMG producers develop samples according to the buyer's requirement and take approval for bulk production. This stage also includes getting approval about apparel, sourcing of raw materials according

to the requirements, PP meeting, etc. Raw materials could be sourced locally or internationally from buyer's approved suppliers. The following steps are included in the Pre-production state [22].

Order Receiving

World's famous retailers H&M, Tesco, Wal-Mart, Marks & Spencer's, ZARA, and other RBO's place POs to the RMG manufacturers that include measurements, barcode, and department name, etc [21].

Strategic Planning

The strategic management team decides how many garments will be produced using how much raw materials and labour hours. This stage includes designing the production plant and preparing machinery to make production efficient [23].

Sample Development

In this stage, RMG firms receive artwork from buyers to develop a sample of the dress according to the artwork provided by the buyer. After accomplishing the sample merchandising department sends that sample to the buyer for approval. The sample development stage is followed by some other interrelated stage as [19].

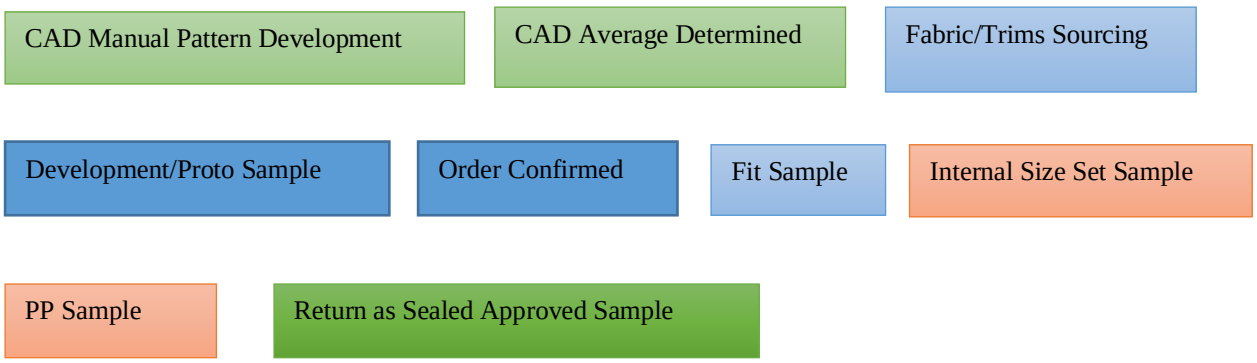


Figure 2. 3: Sample development stages in SCM in the RMG sector of Bangladesh [23]

Material Sourcing

This is one of the important parts of the manufacturing process. In this stage, raw materials should be procured nationally or internationally according to the standard set by the buyer. In the Bangladeshi RMG sector, most of the procurements regarding major parts such as fabrics are done from the international market but garment accessories from the domestic market [19].

Material In-House

Inventories required for RMG production are fabric, nonfabric, trim, and other accessories which are in-house as inventory. After materials are stored, they are checked if physical materials are matched, they qty ordered [19].

Production Process

The bulk production process starts having all raw materials in house. This process includes cutting, sewing, finishing, etc which are described below [19].

Cutting

Different types of machines are used to cut fabric items according to the requirements. Top and bottom parts are usually different than the body part which mainly requires different cutting processes using different types of types of machinery [19].

Sewing/Weaving

A full garment is made by sewing or weaving all cutting fabrics in different production lines [19].

Washing

This is one of the vital processes of production, as sewed garments need washing to get soften but needs extra care not to spoil the colour quality [19].

Finishing

In this stage accessories such as buttons, linings, Velcro, interlining, label, hangtag, shoulder pads are attached with the garments and ready for packing [19].

Post-production process

In this stage thread trimming, checking, folding, pressing, and packing are done. After that shipment inspection and shipment, dispatch is executed [19].

Packing

After finishing and quality checking of garments, folding, pressing, packing, and quality checking of packing are carried out before shipment [19].

Warehousing

All the inspected ready for shipment garments are stored in the central warehouse. Warehouses are used by producers, wholesalers, importers, exporters, finally, the transporters to store all types of inventories [19].

Dispatch for shipment

Stored inventories in the central warehouse are consecutive for shipment. Shipment can be sent via air, rail, or sea but in the Bangladeshi RMG sector, products are shipped mainly via sea, in case of emergency goods can be shipped by air, for instance, any sort of claim by the buyer or to maintain the lead time [19].

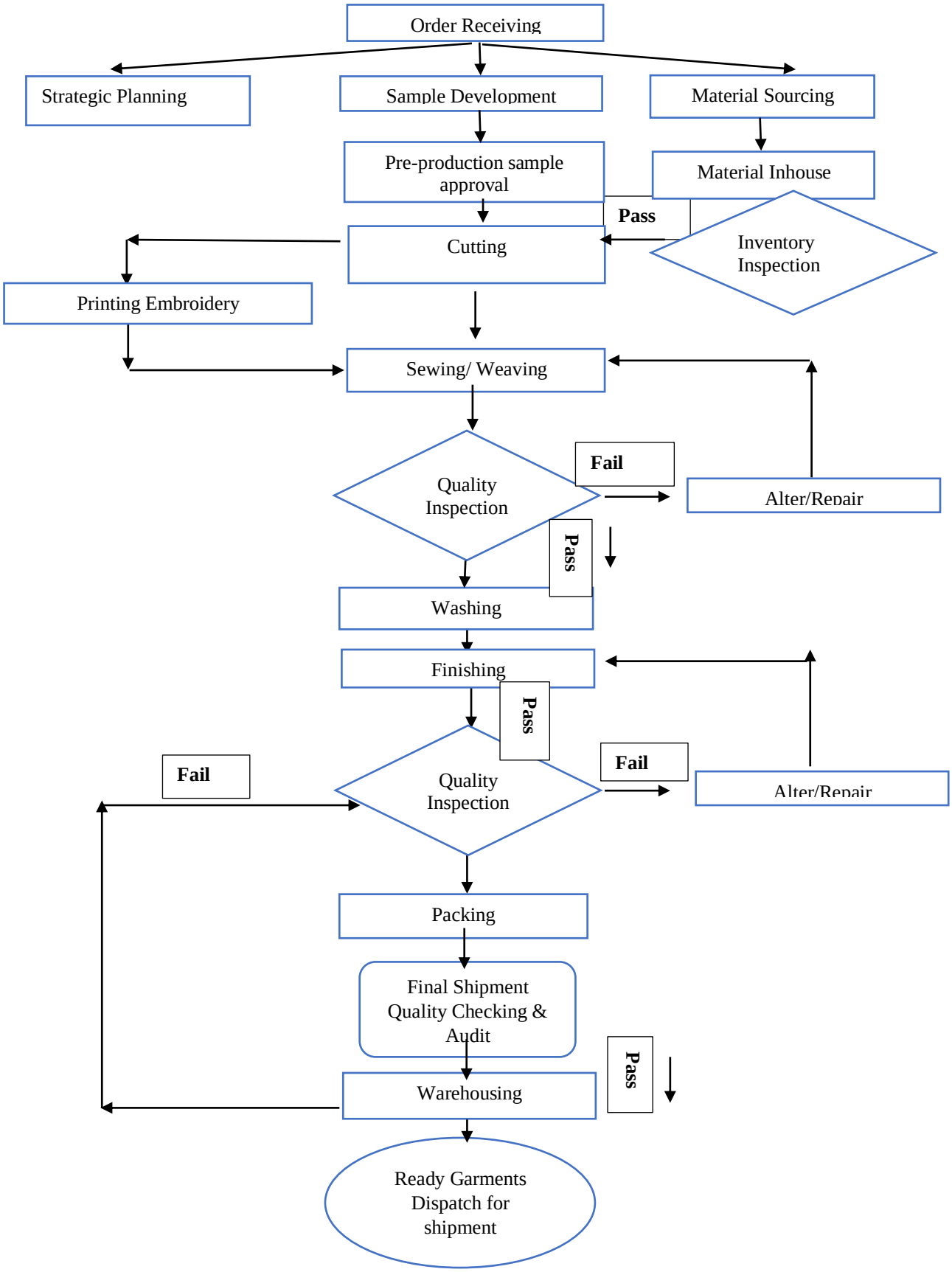


Figure 2. 4**:** Production Flow Chart of RMG sector of Bangladesh [20]

2.4 Robotic Process Automation

People usually put more concentration on creative work, analysis, figuring out problems, and searching for solutions. Discovering a new way of working or creating a new process gives satisfaction. On the contrary, people get bored performing repetitive tasks, since they are putting less concentration on the routine job which results in the job done improperly and less efficiently. Moreover, this is not easy for human beings to update data uninterruptedly to different systems [7].

Consequently, Robotic Process Automation is gaining popularity in organizations that deploy smart software bots to automatize common operation processes throughout the entire business organization [8].

Robotic Process Automation (RPA) is managing and executing high-volume repetitive tasks is usually managed by human effort. This high-volume task includes maintenance of transactions and records, demand calculations, and queries. RPA technology is known as software "robot" or "bot" in short, it imitates a human employee signing into the system entering data, executing all required calculations, and following steps to complete the task. The most significant thing to consider is that this is not part of the IT system of the organization rather an external software assistant to enable existing IT infrastructure quicker and more efficiently. Despite the RPA system first came to light in 2000 but it has reached to maturity state in recent years. RPA system gradually metamorphose from three types of key technologies which are as follows [7]

1. Artificial intelligent
2. Screen scraping
3. Workflow automation

2.4.1 How RPA makes Supply Chain Management Efficient

Removing manual input in Purchase Orders and Other Administrative Tasks

Creating, processing, and responding to a purchase order is a mentionable administrative task for retailers, suppliers, and producers. After analysing the forecast and current stock, demand managers inform the purchasing department to place purchase orders. Robotic process automation keeps on checking the needed inventory levels and the current availability of products in stock. RPA generates purchase orders that move throughout the supply chain without any human involvement. [24]

Response to Questions, proposals and quotes, and other Supply Chain activities

Organizations receive questions from suppliers and other stakeholders. Amongst them, some common queries require a faster response as quotes or proposals. Process automation software such as NLP and RPA to analyse, realize and answer to questions and requests for quotes or proposals. Eventually, suppliers and other stakeholders get quick answers to their queries, quotes, and proposals. [26]

Recognize Repetitive Tasks to Prescribe efficient Process in Supply Chain

RPA applies screen scraping that includes accumulating screen display data from legacy applications allowing users to have tons of data visible in a more modern and accessible way. After analysing this huge relevant data it can be recognized in which area of the supply chain could be improved by reducing waste, enhancing the quality and decreasing delays. By combining predictive actions and prescriptive analytics, RPA continuously and consistently improves the process that makes the supply chain smooth running [7].

Integration with Multiple Systems, Software, and Tools to provide a Performance of robotic process automation is not confined to one platform of the organization. An efficient RPA integrates with multiple software, systems, and tools throughout the organization and works independently. Hence, RPA decreases imitations and enhances speed for organizations, retailers, suppliers, and producers [8].

Inventory management

The most important pillar of the supply chain is inventory. But ensuring the optimal volume of inventory by tracking data efficiently is not that easy. RPO helps continuously monitoring inventory and informing relevant departments when the inventory level is low. Even new shipments can be ordered by RPA completing subsequent tasks properly without any human intervention [32].

RPA helps to track inventory flowing throughout the warehouse to different areas. Tracking thousands of items manually is time-consuming and prone to errors as they are moving through different production lines. This process can be automated by RPA via deploying robots that track moving inventory at each step from selves, production until dispatch for shipment. Precisely, RPA constantly monitors inventory from the time it arrives till it leaves the warehouse [23].

Supply and demand planning

Appropriate forecasting is the benchmark of the efficiency of a supply chain. Usually, managers or demand planners, or analysts do the forecast of inventory needs. Forecasting includes complex data analysis derived from historical sales data, custom orders, market trends so on. These data are to be thoroughly analysed and carefully track down from internal teams, vendors, customers. This process is tiresome, time-consuming, and error-prone [34].

RPA can carry out the whole process quickly and efficiently by merging and organizing required data that enables the analyst to find relevant concise data that requires less time to make decisions. As RPA works with machine learning, it easily follows the set of predefined specific rules along with the trends and purchasing activities of the customer that are easy to miss. All findings are accumulated in a comprehensive report. This report enables planners to efficiently prepare a more accurate forecast with a smaller amount of time and resources. [25]

Purchase order monitor

Purchase order monitoring requires a thorough review process but if all the process steps are to be executed manually, it will be labour intensive and will lead to bottlenecks. RPA processes purchase orders within seconds through automation according to predetermined pricing, quantity, and frequency of purchases. When a purchase order matches approved criteria, it is sent through but if not, the software runs the remaining purchase orders through the procurement manager for systematic reviewing. Consequently, RPA minimizes the number of purchase orders which need reviewal. [26]

Freight management

Till now most of the RMG firms are executing typical transportation and logistics procedures that require huge human intervention as well as working hours. Usually, when a dispatcher gets a load request, he needs to print the email, log into a website to find available loads, log into the company's transportation management system to enter the details, then confirm the request by retyping all the details into the load websites. This one task consumes nearly 20 hours of the dispatcher's time. For instance, the following tasks are being handled manually by the companies [36].

- Shipment Scheduling and Tracking
- Rate lookups
- Load capture
- Invoices
- Inventory management
- Order processing and tracking
- Contract monitoring
- Freight management
- Forecasting [36]

On contrary, freight management is time-consuming and sets of manual tasks. Software bots can provide an efficient and accessible schedule as it works 24/7. It transfers loading information to brokers while they are matching loads with a carrier to deliver it. Additional RPA contributes to the handling of freight claim management, route optimization, and freight accounting. [38].

Return and refunds processing

Properly processing returns and refunds increases the value of the company which is also a high-volume business. This process requires the most human intervention leading the processing workflows to become rapidly overwhelmed.

RPA is the best software to manage return and refund by using predefined task automation software bots can automate many procedures which require human intervention in most cases. Likewise, steps involve in delivering new products, in return management, there are similar steps which easily could be automated. [31]

Invoice management:

Managing invoices is essential for every manufacturing companies specifically in the supply chain and logistics department. A less dedicated invoice management system can lead invoices to slip through the cracks. This labour intensive and tedious task is perfect for automation. After extracting from documents, RPA tracks and enters data accurately. More precisely, it extracts data from invoices, verifies, and sends it to the account manager for approval. The RPA invoice automation software works along with the account manager and purchaser to streamline the account payable process. This process begins with the supplier issuing an invoice to the account email address and ends with the supplier receiving payment. Below are the key actions that are taken by robots to accomplish automatic invoice management operations [33].

- Invoice Automation process
- Processing incoming email messages
- Sending email notifications
- Extracting words off PDF documents
- Entering data into accounting platform
- File transfers to a Microsoft share point online storage system
- Publishing information on power BI dashboard [24]

Mentionable benefits of the invoice automation process are as below.

- Eliminates printing hard copies of invoices.
- Reduces data entry and admiration costs.
- Improves cash flow.
- Ensures information accuracy.
- Increase system stakeholder awareness through email notifications.
- Allows 24/7, uninterrupted accounts payable processing.
- Enables employees to eliminate some mundane tasks and increase morale. [36]

Price investigation and comparison:

The most effective way to minimize expenses in the supply chain is to optimize the pricing of sourced materials. But manual price lookup for thousands of products through multiple options is overwhelming. Software bots frequently search for pricing data on certain materials, routinely updates the procurement database that makes price comparisons for the purchasing department results in a better purchase price. [23]

2.4.2 ERP Integration

RPA integrates all types of ERP and enables viewers to have a holistic view of entire enterprise resources. Software bots work 24/7, enters accurate data, and automates integration between applications freeing up staff for customer-facing tasks. Simultaneously, notifies errors or delays which scale up operations quickly and cost-effectively. Report generation is another great use of automation which is usually generated at night off hours so that they are available for everyone at beginning of the next day. Software bots can be used to

continuously monitor the database for inventory and sales, thresholds are set and then be notified when that inventory hits a certain point. The next subsequent task is to put together a PO and order the next batch. Since the main task of ERP integration is extracting data and entering them into the needed field which is done by RPA efficiently as it can read data on PDF file, email, spreadsheet, and database. [31]

2.4.3 Conclusion

Cloths are one of the basic needs of humans, a way of aesthetic expression and symbols of aristocracy. The garment industry is the biggest sector to earn foreign revenue and providing a job for many developing countries as Bangladesh. The country has a huge workforce, natural resources, raw materials, and production premises to produce world standard apparel but the inability to maintain lead time persuades many RMG firms to refuge many work orders. In developing countries, human resource is recruited at cheaper wage to manage supply chain activities, therefore, lower salary convinces firm owners not to think about process automation. There are some steps of the supply chain which are restricting production activities and lengthening the production period. Since apparels comprise lots of accessories that need to be procured from various vendors following the manual purchase process. Likewise, warehouse management, demand planning, invoice management, postproduction processes, for instance, transportation planning are being managed in an old-fashioned way are also responsible for lead time prolongation. As mentioned, preproduction and postproduction activities could be automated using robotic process automation. As RMG firms are producing for the world's famous brands, their production activities are world standard. Although the most updated production process is followed but there are still some areas that could be automated such as fabric racking, accessories racking, button fixing, and cutting with robotic arms. Robotic process automation in association with machine learning and artificial intelligence can help human employees to carry out repetitive tasks appropriately within an incredibly short period. Simultaneously, RPA bots can communicate information immediately to the relevant departments, while human employee needs much more time to execute the same action, since repetitive task, human employees lose concentration which results in unintended errors. At the same time, human employees cannot communicate the updates to the relevant departments as fast as RPA bots can do. Process automation not only increases efficiency but also reduces cost significantly. Eventually, automation does not mean to substitute a human employee with robots, rather it means that robotic process automation could help the human employee to make the process more accurate and more efficient.

CHAPTER THREE: METHODOLOGY

This chapter depicts how the author of this research attained the solutions to the research questions through literature, research strategies, research design, research methods, data collection methods in different types of approaches. After analysing potential research methods, the qualitative case study method seems to be the best fit to attain the objectives, therefore, the qualitative research method is used in this research.

3.1 Research design

An appropriate methodology is needed to obtain specific data related to the topic and examine the variables to reach a comprehensive conclusion. This chapter explains the procedures followed to explore the research topic and the objective to accomplish the research. Specifically, how the problems are identified, analysed, and evaluated. In addition to that, the necessities, strengths, and weaknesses of other research approaches are discussed, the ways of collecting required data, development of questionnaires, and focus group are also mentioned. Theoretical and empirical approaches are applied to collect relevant data. Quantitative methods are followed to figure out underlying objectives. There are two basic ways of conducting research which is either via a precise research question by visiting the company or open-ended questionnaires that include different types of relevant questions, analysing them leads to the required conclusions.

Case Study as a research method

The case study includes step by step holistic description of a process, event, or occurrence of a company or an organization. Researchers monitor the outcomes and strategy development to pick relevant data to find the inconsistencies that might be overcome by system reincarnation [9]. To identify if the case study research method is satisfying the needs, it is important to evaluate and score the outcomes carefully to enable the researcher to reach the solution [10].

In this research, I have chosen the case study method of *Viyellatex* RMG manufacturer, as I am trying to figure out the factors that have a potential influence on delaying the lead time if could be automated.

3.2 Scientific view in methods of a research

Positivism

This is a philosophical system embedded in science and mathematics based on the theory that every existing system can be asserted via observation, experiments, and mathematical logic. The existing things, processes, systems can be challenged, defined, measured, improved, or reduce to benefit mankind. According to positivism all types of phenomena are either true or false or do not make any sense. Concisely, through positivism, by utilizing mathematical logic and scientific procedures this is possible to conclude whether a process could be improved or should be replaced [12].

Hermeneutics

This term derived from theology provided a clear understanding of human action when social science is concerned. It emphasizes to realize from the view of social actors. The main concern is to perceive the main concerning point based on interpreted shared experience by human beings and their perceived knowledge. Hermeneutics expresses that all existing phenomena benefiting, or harming mankind, in reality, are created by a human being [11].

Scientific Point of View of This Research

Positivism as a scientific approach is followed in this research because, theories from books, articles, and journals are used to figure out procedures to offer recommendations. Empirical data has been collected via online interviews, emails, questionnaires from the responsible persons in a different part of the supply chain in Viyellatex. Respondents did their best according to their knowledge, observation, and experience to provide relevant information at their earliest. Hence, problems are figured out and recommendations were proposed according to empirical data modern research, and theory [12].

3.3 Different Scientific Approaches

Deductive method

Defines that the deductive approach of research starts with an idea that goes throughout many research processes to attain the objective. There are one or several research questions that steer the research activities in the correct direction. Ideas are obtained to support the research process. Initially, it progresses based on the literature review and collected empirical data. The deduction is formulated either theoretical or practical. Eventually, the outcomes of the study process are drafted for future analysis. Thus, research is concluded, recommendations are provided and scope for future research is proposed [13].

Inductive method:

This method is a kind of mirror image of the deductive method which develops a theory based on observation of certain events. Empirical data, observations, and investigations gradually turn into theory under a systematic procedure. Although this method is suggested for both quantitative and qualitative research, it is found to be used mostly for qualitative research [14].

Scientific Approach applied in this research

The deductive approach has been used in this research since this is based on theory and empirical data leading towards resolution. The conventional “top-down” method leading towards findings, at the end backed by literature review. The findings of this report turned the hypothesis into real factors and suggested automating some steps of the supply chain of Viyellatex to shrink the lead time as well as to make the whole supply chain more efficient. To acquire needed information, concerned personnel were contacted via email, skype, and telephone [See Apendix-2].

3.4 Research Method

Quantitative approach

The quantitative method helps to figure out problems related to human beings or society and provides a solution by testing a theory that comprised variables, statistical analysis, measuring numbers to identify if the problem was figured correctly [14]. The quantitative approach emphasizes character measurement and data analysis based on the characters provided by people and their activities, the quantitative method combines the outcomes of dependent and independent variables, gives a numerical shape to their effect. After proving scientifically un-measurable as measurable, this method provides the apprehensive credible result [15].

Qualitative method

The qualitative method helps to perceive human beliefs, attitudes, experiences, behaviour, and ideology. This method contributes obtaining the result by adding new dimensions to interventional studies that cannot be derived through variable analysis alone [14]. The qualitative approach can make studies more extensive by involving user experience on it. This approach focuses on three areas, which are, documentary or textual analysis, interview studies, and observational studies. The qualitative approach ensures everyone's involvement which helps to reincarnate the whole process. The participants have an influential role in the study by raising their voices about the benefits and detriments of the study. The qualitative research approach has a significant impact on data collection, its analysis, and result interpretation. To have successful research through a qualitative approach, the aim of the research should be well-organized, as the research progresses, it should be scrupulously adjusted, there should be a re-defined method to nullify research bias [15].

Research Methods of the Thesis

The research is based on both qualitative and quantitative approaches since process simulation was designed based on the experience of the concerned person and numeric data of supply chain process simulation has been used and analyse to figure out the bottlenecks and to propose a better solution. Quantitative research helped derive competitive data, for instance, process time, the corresponding costs about current operations, if could be made the current operation more efficient. The qualitative approach allowed the author to have the luxury to ask back the preliminary participants why and how. The author had to listen carefully replies of respondents to make them elaborate and answers the relevant questions whenever needed. To carry out this research, semi-structured interviews have been conducted, and supply chain operation related questionnaires have been sent to acquire needed data from Viyellatex (see Appendix-2). The structure of the supply chain has been acquired through interviews, and other information such as cycle time and cost has been acquired by questionnaires and case studies. Collected data has been put to simulation software, processing time, KPIs, and the corresponding cost has been observed and analysed. After finding the bottlenecks, If manual processes had been replaced by RPA (Robotic Process Automation), supposed new costs and cycle time have been put into the simulation, new data have been recorded, analysed to find out to what extend the KPI has been improved. The cost of replacing the manual process with RPA and benefits of process efficiency have been weighted in terms of finance and an action plan has been proposed to Viyellatex.

3.5 Data Collection Source

Primary sources

Usually, research methodology includes two types of data collection methods to get required data which are the primary source of data and secondary source of data. Primary data serves to provide specific data to figure out a certain case or problem. Observation techniques, personal interviews, and surveys are carried out to accumulate information about primary data. A personal interview is taken either face to face or using online media like email, phone, skype, or other forms of communication media [16].

There are two ways to take a personal interview, a structured way, and an unstructured way. Predefined open-ended or close-ended questions are used in a structured interview to get a complete picture of the processes or problems. On contrary, in an unstructured interview, interviewers do not follow any question pattern rather try to collect required information through a friendly conversation [16].

Secondary sources

Secondary data include published and unpublished written materials i.e books, articles, journals, thesis work which are easily accessible and can be accessed by someone whenever needed. Researches are mostly done using both primary and secondary sources of data. Secondary data serves as supplementary while primary data is not precise enough. As secondary data source comprises a variety of data, statistics, graphs, and charts, it helps researchers to make a mathematical model or simulate through software to get a more precise overview [17].

Data Collection Method used in Thesis

Both primary and secondary data have been collected and used in this research. Primary data has been collected via interviews and questionnaires from the responsible persons of a different stage of the supply chain in Viyellatex. To have a holistic view about each step of the supply chain open-ended questions have been sent via emails to some managers, some of them have agreed to skype interviews, some informed their view over social media chat. Financial and other data have been collected from the Viyellatex website. Since I used to be one of the suppliers of raw materials to this firm, I have some personal relationship with some managers, they have provided me some confidential data which have helped me significantly to outline the findings. Literature has been found mostly from books, journals, scientific articles available in the Taltech library. The rest of them were searched in the search engine like google and emerald. Since robotic process automation in supply chain management of the readymade garment industry is not yet that much popular, search engines could not provide with comprehensive data. There are many lectures, campaigns, seminars, and discussions about RPA in SCM are available online which helped me to have the full insight.

Summary of methodology

The author has intended to include the most relevant research approaches to attain the objectives of the research within the stipulated time and limitations. The case study method was found to be the most appropriate method to have a holistic view of step by step supply chain process automation and its impact on operational efficiency.

The scientific view of the research is positivism because robotic SCM process automation is explained through mathematical logic to conclude whether current manual SCM processes could be replaced by robotic process automation. The outcomes of this research have been given a numerical shape using a quantitative research method as well as tested the variables, statistical analysis, numerical data. Since some data have been collected through interviews and questionnaires, the qualitative method is used to acquire the most relevant and precise information. To recommend solutions to the identified problems, the deductive approach has been used since this approach suggests the conventional "top-down" analysing using the empirical data backed by literature review. Required data has been collected through both primary and secondary data collection methods to have a holistic view of the supply chain operation of the company.

Approaches	Applied
Research strategy	Case study
Scientific perspective	Positivism
Scientific approach	Deductive
Research method	Qualitative and Quantitative
Data Sources	Primary and secondary

Table 1. 4: Summary of Methodology used in this thesis

The rationale behind using Aris 10 Architect and Designer Simulation Software

Aris 10 Architect and Designer is one of the best business process designer software containing more than 200 model types to help to explain the whole business process meticulously. It enables users to explain the relationship between processes, used resources, and operating environment precisely. Aris10 provides easy to use design, formatting, and rocket search tools during process design. The business model could be designed in four layers such as value chain mapping to explain the process structure known as value-added chain (VAC) diagram, stage level designing known as Event-Driven Process chain (EPC), activity level modeling known as function description, finally modeling the tasks. All layers are interconnected that allows identifying the links and stages. Models can be restored, modified, saved to view when needed. Multiple users can design different parts of the business process and access the data remotely. A wide range of formatting styles and templates reduce training efforts, in addition to that, there is a choice to create users' symbols to represent special processes crucial present to the stakeholders. Simulation can be done by inserting real operational costs, time, and many other measures to have a realistic result. The simulation result is evaluated based on Key Performance Indicators (KPI) to take appropriate initiatives to improve the efficiency. Result can be presented via charts, text, or table form. Output can also be produced through different formats such as HTML, TXT, PDF, DOC, XLS etc.

CHAPTER 4: DATA ANALYSIS AND FINDINGS

In this chapter supply chain and production steps of Viyellatex will be described. Each step of supply chain and production has been designed and simulated with ARIS Architect & Designer 10.0. Data has been analyzed to find bottlenecks. The steps that appeared as bottlenecks experimented if those steps could be automated with Robotic Process Automation (RPA). Feasible steps were replaced by robots and simulated again until bottlenecks and waiting time reduces.

4.1 Basic organizational and operational model of Viyellatex

Viyellatex is one of the best readymade garment manufacturers and exporters in the Bangladeshi readymade garment industry. It has been exporting knit and woven wear to many world-renowned brands as Marks & Spencer, Tesco, Puma, GAP, G.star, etc. basic operational model of Viyellatex is as follows. We will be simulating and analyzing results specifically for pre-production, production, and post-production steps to identify bottlenecks and the possibility to automate them. Below are the components of pre-production, production, and post-production processes [30].

Pre-production Processes	**Production Processes**	**Post-Production Processes**
Demand Planning	Fabric Preparation	Transport planning
Raw material procurement	Accessories Preparation	
Supplier's Invoice preparation	Fabric & Accessories Fixing	
	Apparel Final Finishing	

Figure 4. 1: Organizational and Operational Model of Viyellatex (Source: Made by Author)

Description of different types of diagrams drawn using Aris 10

Defining a value-added chain diagram, and its contribution to competitive analysis

A value chain diagram provides a visual model of business activities required to complete an entire business cycle starting from the production of a product to delivering them to the final customer. Usually, a value chain diagram includes planning, designing, production, promotion, and logistics activities. A value chain diagram enables its user to identify possibilities to improve competitive advantages, efficiency, and profit margins. Similarly, the value chain diagram helps to detect which processes are making customers pay for, which processes are existing as waste and which processes are mandatory to complete the processes, but customers are not paying for them. A value chain analysis helps to reduce non-profitable business steps and to make current profit steps more competitive. There are five basic areas are included in the value chain diagram which are inbound logistics, operations, outbound logistics, marketing, and sales, finally the after-sales services. Inbound logistics ensure raw materials procurement, receiving, storing overall inventory control. In the operational phase, inputs are converted to the desired output through machining, assembling, equipment handling, and testing. The outbound phase includes finished product storing, order processing and scheduling, delivery vehicle operation to send finished goods to the final customer. Sales and marketing comprise quoting, advertising, channel selection, promotion, pricing, and perform all necessary steps to make the customer aware of the product and to make the purchase. Finally, in the service step, producers maintain or enhance the value of the product through installation, repair, and training [31].

EPC (Event-driven process chart)

To define the EPC diagram, this is a diagram derived from architecture and integrated software system, known as event-driven process diagram which is used in business resource planning in the form of a flow chart to identify feasible areas of improvement.

EPC diagram is used to describe business processes and workflows, more precisely this is an event-driving process chain modelling language. Each EPC diagram starts and ends with an event which is a condition that must satisfy the requirements of the start and end process. One event might include multiple functions and vice versa following certain rules. These rules are known as 'AND' "OR" or" XOR" which act as graphical connectors. This process is used at the preliminary stage of the process hierarchy. An EPC diagram is one of the best ways to describe technical flowcharts and workflows as well as the whole Business process modeling notations. Recently, many industries are preferring EPC diagrams since it is supported by different tools such as SAP a widely known ERP software which documents its SAP R/3 solution using EPC diagrams. The amazing beauty of this diagram is business processes could be drawn rapidly and exists as an automatic framework to input data, simulate and analyse throughout an organization to improve its resource planning [31].

Value chain diagram of Viyellatex

The entire value chain diagram of Viyellatex includes four main steps which are pre-production processes, inbound preparation, post-production processes, production processes, and post-production processes. The preproduction process comprises demand planning, raw material procurement, suppliers invoice preparation. Through the inbound preparation process fabric and accessories are made ready for production as well as the packing materials. The production process consists of fabric and accessories preparation, sewing, and final finishing of apparel. The post-production process comprises picking, packing, and transport planning [29].

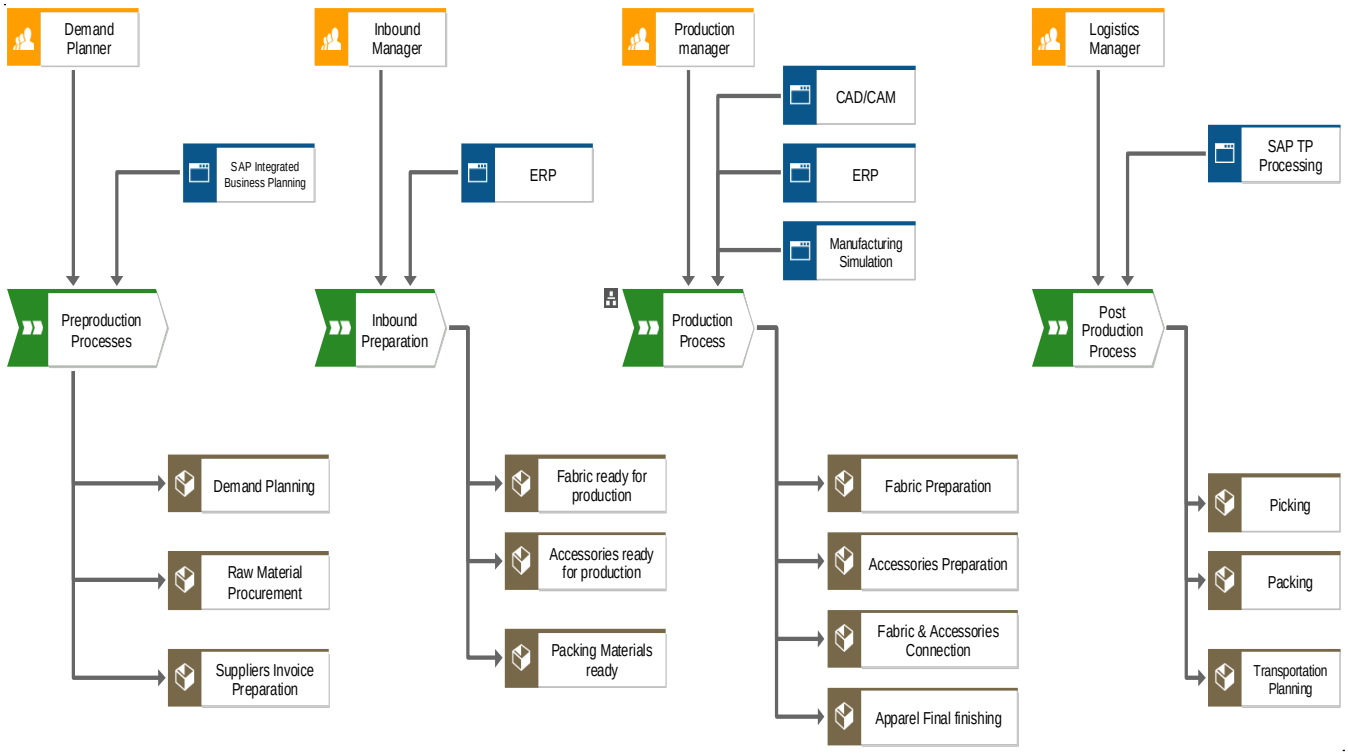


Figure 4. 2: Value Chain Diagram of Viyellatex (Source: Made by Author)

4.2 Preproduction Processes

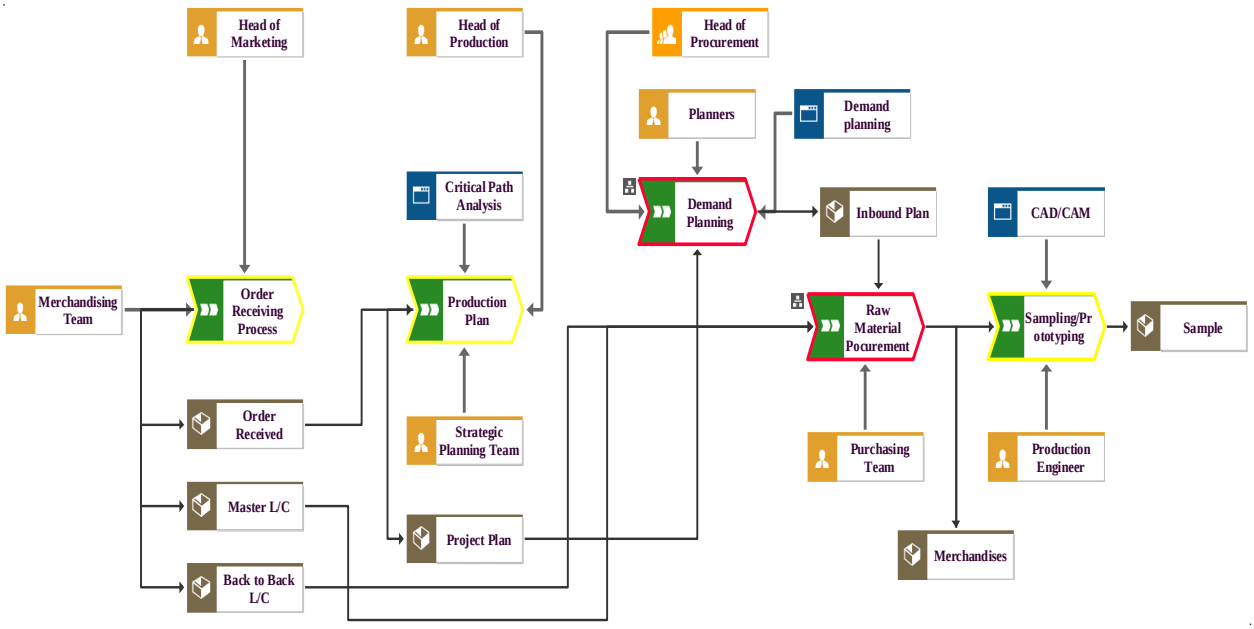


***Figure 4. 3**: Value Chain Diagram of Pre-production Process of Viyellatex (Source: Made by Author)*

Members of the marketing and merchandising department headed by the marketing manager negotiate and confirm orders if price, style, and delivery date match. After the order has been confirmed, a critical path is made by using Microsoft project software based on available data to produce ordered material within the stipulated time frame. The second step is to receive from the buyer the Letter of Credit (L/C) which is also known as Master L/C. This is the purchase contract in favor of the manufacturer which includes business terms and conditions, incoterms, unit price, shipment date. Based on Master LC, another type of LC is opened by the manufacturer which is called BTB LC (Back to Back L/C) in favor of suppliers to get credit in raw materials procurement. The third step is to make a project plant in presence of a buyer's representative, technical manager, procurement manager production manager, logistic manager, and quality manager to determine the men, machine, and production lines required to attain the projected shipment date. The Fourth stage is to estimate raw materials demand considering a current stock, expired item, and lead time of MTO (Make to order) materials. The fifth and final stage is to develop a prototype based on the buyer's specification. After the prototype is developed, it is sent to buyers for approval. In demand planning and raw materials procurement, some bottlenecks are found due to manual handling, which is highlighted as '**RED'** border to elaborate explicitly as follows.

4.3 Simulation result and process explanation of EPC Diagram of Demand Planning

The prior state of demand planning is to track how much inventory available and how much is to be expired. The whole process is carried out by WH employees which could be automated by robots to check out-of-stock items, errors in labels, or missing labels by using RFID. Another important fact is to inform the procurement department when a minimum level of the inventory falls below the safety level which takes much more time for a human employee than robots. Below are the simulation results having all procedures done by a human employee and one step replaced by a robot. Key areas are highlighted with red while jobs are done by a human employee, in contrary key areas are highlighted with green while jobs are done by robots (See diagram in Appendix-03).

Performing demand planning by human employee we have bellow simulation results

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Checking remaining stock/phased out materials	30	19	3590:00:00	719:00:00	10	***12650***
Planning demand based on the forecast	19	19	0:00:00	228:00:00	0	
Collecting demand from different departments	30	20	3381:00:00	719:00:00	9	
	79	***58***	***290.4583333***	***69.416667***	***19***	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *EMPLOYEE* = Total Function Cost/Total Processed Cycle)	***218.1034483***					

Performing store activities by Robots, we have below simulation results

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Phased out/raw material need checked by Robots	30	30	0:00:00	180:00:00	0	***11500***
Planning demand based on the forecast	20	20	0:00:00	240:00:00	0	
Collecting demand from different departments	20	20	3381:00:00	719:00:00	9	
	70	***70***	***140.875***	***47.4583333***	***9***	
PER PROCESS COST CALCULATIONS BY ROBOT						
Per process cost while handled by *ROBOT* = Total Function Cost/Total Processed Cycle)	***164.2857143***					

Findings:

While tracking inventory status by a human employee to identify which items are outdated or below safety stock, it takes much more time during one cycle that results in a dynamic wait time of **3590 hours**. Consequently, the process folder managed to process **19 pcs** out of **30 pcs** received having a total processing time of 180 hours, and a total processing cost of **EUR 12650**.

On the other hand, we can replace only one step with a robot which is inventory tracking and sending notifications to the procurement department if the inventory level drops below safety stock. If we replace this step with a robot, we experience a significant increase in efficiency. Dynamic wait time reduced to **"0" hours** which previously was **3590 hours**, consequently, the system can process all units it receives for example previously, inventory tracked by the human employee it managed to process **19 out of 30 pcs** but now it managed to process **30 out of 30 pcs**. Similarly, total processing time reduced from **719 hours to 180** having cost reduction as well from **EUR 12650 to EUR 11500**.

Per processes cost while handled by the employee is around EUR 219 while handled by robot, it is EUR 165.

4.4 Basic EPC structure of raw material procurement

In the EPC structure, how raw materials are procured is described. Initially, simulation has done highlighting functions borders in green for value-added functions, in yellow for non-value added and must do functioned, in red for bottlenecks and storage areas. Bottlenecks and steps which have the possibility of automation are marked red, changed per unit cost, execution time, and simulated again. Both simulation structures visible in Airs 10 are presented as below alternatively. Findings, process, and comparison were depicted in a row.

In the first procedure, when the inventory level drops, the warehouse employee releases purchase requisition to the purchase manager to select a vendor and to procure raw material through the purchaser. The vendor is selected, and the purchase order is placed to the vendor by the purchaser after matching the quote provided by the vendor. Procurement manager checks if the delivery date meets the project plan if does not meet, he searches for an alternative vendor, if the delivery date is aligned with the project plan he proceeds with further steps. Warehouse employees receive materials, inspect and post GR. The processes are dealt manually. The first simulation was run having manual process handling, working hours, and cost were put according to data found from Viellatex Ltd. Some processes found feasible to be replaced by software bots. Those steps have been highlighted with a red border and replaced by RPA bots in association with ERP software and simulated again. Below results have been found by simulating having process done manually by human employees and process done automatically by RPO bots (See diagram in Appendix-03).

Simulation result having procurement procedure done by the human employee using only ERP

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Making Purchase Requisition	30	16	4705:00:00	819:00:00	13	***2880***
Supplier issued invoice via Email	0	0	0:00:00	0:00:00	0	
Inspecting Material	0	0	0:00:00	0:00:00	0	
GR Posting	0	0	0:00:00	0:00:00	0	
Searching another vendor who can deliver earlier	1	1	0:00:00	30:00:00	0	
Analyzing If Delivery date meet production need	1	1	0:00:00	20:00:00	0	
PO Placing to Vendor	4	1	990:00:00	35:00:00	2	
Vendor Selection	16	8	2626:00:00	320:00:00	8	
Making Sales Agreement	0	0	0:00:00	0:00:00	0	
Preparing Purchase order	8	4	1200:00:00	240:00:00	4	
Receiving Material	0	0	0:00:00	0:00:00	0	
	60	***31***	***396.7083333***	***61***	***27***	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *EMPLOYEE* = Total Function Cost/Total Processed Cycle)	**92.90322581**					

Simulation after having software bots in association with ERP

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Making Purchase Requisition by RPA bots integrated in SAP	30	30	0:00:00	150:00:00	0	***6305***
Supplier issued invoice via Email	2	2	0:00:00	0:00:00	0	
Inspecting Material	8	5	1235:00:00	250:00:00	3	
GR Posting by RPA bots integrated in SAP	5	2	777:00:00	8:00:00	3	
Searching another vendor who can deliver earlier	18	17	0:00:00	519:00:00	0	
Analyzing If Delivery date meet production need	30	29	0:00:00	585:00:00	0	
PO Placing to Vendor by RPA bots integrated in SAP	30	30	0:00:00	90:00:00	0	
Vendor Selection by RPA bots integrated in SAP	30	30	0:00:00	120:00:00	0	
Making Sales Agreement	11	11	0:00:00	220:00:00	0	
Preparing Purchase order by RPA bots integrated in SAP	30	30	0:00:00	180:00:00	0	
Receiving Material	11	8	1292:00:00	355:00:00	2	
	205	***194***	***137.6666667***	***103.20833***	***8***	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *ROBOT* = Total Function Cost/Total Processed Cycle)	**32.5**					

Findings:

There is a significant improvement found after including RPA bots. After RPA installation, within a cycle time, **30 units** were received out of **30 units** while it was **16 units** out of **30**. All other functions which did not even move for further processing within a specific period, after installing RPA all of them moved for further processing almost equal to the unit received for further processing. Dynamic wait time and total processing time have been reduced significantly almost for all items except processes handled manually. Function cost increased from **EUR 2880** to **EUR 6305** in RPA because function received and processed more units than before.

Per processes cost while handled by employees is around EUR 93 while handled by robots it is EUR 32.

4.5 Simulation result and process explanation of EPC Invoice processing model by both human employees and some steps with RPA bots

In the first place, the invoice is managed manually by finance employees until the invoice gets paid. The first task of the process is to automatically locate and download the PDF invoices from dedicated email addresses where all invoices are sent by suppliers. After downloading, finance employees extract relevant information and shorts them base on suppliers, for instance saving them specific folder as YKK zippers, VIYELLATEX accessories, BEST BUTTONS for future trace out. Purchasers and account managers are notified about the arrival of invoices. All information is updated in a dashboard. Purchaser got disbursed email and matched with vendor quote and GRd materials. If all information is aligned, invoiced are approved and the account payable manager makes the payment. If all information is not aligned, the purchaser either contacts the vendor for a credit note or initiates a claim for missing materials. Some lengthy manually managed steps are identified to be feasible to replace with RPA bots which are **locating and downloading invoices, short invoices by suppliers, extract relevant information from invoices, sending email notifications, and update information on a dashboard.** The border of these steps is highlighted with bold red lining, putting processing hours while RPA bots execute them, simulated and populated the result as below (See diagram in Appendix-03).

All processes are executed by human employee bottlenecks are highlighted in orange

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Update information on a dash borard	1	0	119:00:00	0:00:00	1	***2800***
Accounts payable manager make the payment	0	0	0:00:00	0:00:00	0	
Short Invoices by Suppliers	13	6	2573:00:00	120:00:00	7	
Invoice is approved for payment	0	0	0:00:00	0:00:00	0	
Purchaser matches invoice with quote and GRd material	0	0	0:00:00	0:00:00	0	
Locate and Download invoice	30	13	5864:00:00	539:00:00	16	
Invoice disbursed to Purchaers	0	0	0:00:00	0:00:00	0	
Extract relevant information from invoice	6	2	1296:00:00	40:00:00	4	
Sending Email Notifications	2	1	559:00:00	20:00:00	1	
	52	***22***	***433.7916667***	***29.958333***	***29***	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *EMPLOYEE* = Total Function Cost/Total Processed Cycles	**127.2727273**					

Some steps are executed by RPA bots and results are highlighted in green

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
RPA bot Updates information on a dash borard	30	30	0:00:00	90:00:00	0	***14520***
Accounts payable manager make the payment	25	25	0:00:00	200:00:00	0	
RPA bot Shorts Invoices by Suppliers	30	30	0:00:00	180:00:00	0	
Invoice is approved for payment	26	25	0:00:00	180:00:00	0	
Purchaser matches invoice with quote and GRd material	29	29	0:00:00	348:00:00	0	
RPA bot Locates and Download invoice	30	30	0:00:00	150:00:00	0	
Invoice disbursed to Purchaers	30	29	0:00:00	233:00:00	0	
RPA bots Extract relevant information from invoice	30	30	0:00:00	120:00:00	0	
RPA bot Sends Email Notifications	30	30	0:00:00	120:00:00	0	
	260	***258***	***0***	***67.541667***	***0***	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *ROBOT* = Total Function Cost/Total Processed Cycles	***56.27906977***					

Findings:

As the result above is discernible, after making some steps automated all units are processed which are received while handling by the human employee it was around **50%** and even below **50%** for some steps. Dynamic wait time reduced to **'0'**. The Sum of processing time increased because all units were entered into the system within the same cycle since processing time was reduced for each process function. Function cost is higher than the previous table because all functions repeated many times within the same cycle due to reduction of processing time for the automated steps.

Per processes cost while handled by employees is around EUR 127 while handled by robots it is EUR 56.

4.6 Simulation result and process explanation of EPC diagram of fabric preparation model by both human employees and some steps with RPA bots

Inhouse fabrics are racked by production employees and inspected by quality control employees. Fabrics with problems are returned to the vendors and fresh fabrics are processed through, **Fabric Spreading, Marker Setting, Grouping, and Cutting.** All processes are done by the employee with automatic machines. There is no possibility of automation in those processes since they are handled by the world's most modern technologies except the **Cutting** process. In the cutting process, there is a possibility of improvement since human employees execute this process with cutting machines which can be fully automated by robots. If measurements are entered for all parts of the fabric, robots can perform all types of cutting jobs without human touch. After that fabric is processed through **Shorting and bundling, Scissoring, Numbering, Isolating Outputs to fit in different suitable operations, Panel Replacement, and Racking**. Amongst these processes, the only possibility of automation is racking which can be done by robotic hand. Simulation is done without automation and automation for cutting and racking below results are found (See diagram in Appendix-03).

Simulation result before automation of some steps

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Shorting and Bundling	2	1	76:00:00	16:00:00	1	9680
Scissoring	1	1	64:00:00	20:00:00	0	
Fabric Inspection	30	30	0:00:00	360:00:00	0	
Fabric Spreading	26	15	3184:00:00	120:00:00	11	
Isolating outputs to fit in different suitable operations	1	1	0:00:00	8:00:00	0	
Cutting	9	2	1902:00:00	406:00:00	6	
Numbering	1	1	0:00:00	10:00:00	0	
Checking Replacement with Vendor	4	4	0:00:00	64:00:00	0	
Racking Scissored Fabric	1	1	0:00:00	8:00:00	0	
Panel Replacement	0	0	0:00:00	0:00:00	0	
Marker Setting	15	12	1745:00:00	72:00:00	3	
Grouping	12	9	1238:00:00	63:00:00	3	
Fabric Racking	26	26	0:00:00	260:00:00	0	
	128	**103**	**342.0416667**	**58.625**	**24**	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *EMPLOYEE* = Total Function Cost/Total Processed Cycles	**93.98058252**					

Simulation result after automation of some steps

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Shorting and Bundling	11	8	880:00:00	128:00:00	3	13560
Scissoring	8	6	713:00:00	126:00:00	1	
Fabric Inspection	30	30	0:00:00	360:00:00	0	
Fabric Spreading	26	21	2051:00:00	168:00:00	5	
Isolating outputs to fit in different suitable operations	6	6	0:00:00	48:00:00	0	
Cutting by Robots	12	11	101:00:00	557:00:00	0	
Numbering	6	6	0:00:00	60:00:00	0	
Checking Replacement with Vendor	4	4	0:00:00	64:00:00	0	
Racking Scissored Fabric by Robots	6	6	1:00:00	18:00:00	0	
Panel Replacement	0	0	0:00:00	0:00:00	0	
Marker Setting	21	16	1647:00:00	96:00:00	5	
Grouping	16	12	1255:00:00	84:00:00	4	
Fabric Racking by Robots	26	26	1:00:00	130:00:00	0	
	172	**152**	**277.0416667**	**76.625**	**18**	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *ROBOT* = Total Function Cost/Total Processed Cycles	**89.21052632**					

Findings: After automation cutting and racking, the processed folder received units in the same cycle increased significantly by around **50%**. Previously, in the same cycle, cutting could be done **2 units** out of **9 units**, now since cutting time per unit and racking time reduced, **12 units** are sent and **11** out of which are now processed. Due to including robotic arms, racking material for further processing now increased to around **100%**.

Per processes cost while handled by employees is around EUR 94 while handled by robots it is EUR 89.

4.7 Simulation result and process explanation of EPC Diagram of Accessories preparation for apparel production

This process is the same as the fabric preparation process, accessories are in-house by production employees and inspected by quality employees to find out if there is any problem with accessories. Defected Accessories are sent to vendors for replacement or credit note. Perfect accessories are racked for fixing in the sewed clothes. There is no scope to automate all steps of accessories preparation since this is a human-based job, employees execute using modern machines and accessories. There is only option to automate is to rack them using robotic hands. Below is the simulation result before using the robotic hand and after using the robotic hand (See diagram in Appendix-03).

Simulation done before automation

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Accessories Racking	27	26	0:00:00	525:00:00	0	*9040*
Checking Replacement with Vendor	3	3	0:00:00	48:00:00	0	
Accessories Inspection	30	30	0:00:00	540:00:00	0	
	60	***59***	***0***	***46.375***	***0***	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *EMPLOYEE* = Total Function Cost/Total Processed Cycles	***153.220339***					

Simulation result after automation

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Accessories Racking	27	27	0:00:00	135:00:00	0	5190
Checking Replacement with Vendor	3	3	0:00:00	48:00:00	0	
Accessories Inspection	30	30	0:00:00	540:00:00	0	
	60	***60***	***0***	***30.125***	***0***	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *ROBOT* = Total Function Cost/Total Processed Cycles	***86.5***					

Findings:

After automation of accessories racking, in the same cycle, the processing unit receives all units and processed them all with less processing time than before. There is not dynamic wait time and the total cost is also reduced significantly. The total cost of processed cycles was reduced significantly from **EUR 9040** to **EUR 5190**. One racking process cycle was received more while handling by robots than while handling human employees.

Per processes cost while handled by employees is around EUR 153 while handled by robots it is EUR 86.

4.8 Simulation result and process explanation of EPC diagram of fabric and accessories connection

Processed fabric and accessories are entered into the sewing line to fix them together to make the final knit or woven cloth. If some units are found stained since they went through many processes, they are isolated and sent for washing again. Clean apparels are entered button fixing area to have the button and hang tag attached. Quality employees execute a final check if everything is alright. Apparels with quality issues are sent to the relevant department for having the problems fixed (See diagram in Appendix-03).

Simulation is done before automation

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Washing Plant	20	20	0:00:00	320:00:00	0	13820
Sending Relevant Department to fix the problem	0	0	0:00:00	0:00:00	0	
Apparel go through Final finishing	4	0	1371:00:00	505:00:00	3	
Quality Check	4	4	0:00:00	320:00:00	0	
Sewing Line	30	30	0:00:00	540:00:00	0	
Isolating outputs to fit in different suitable operations	30	29	0:00:00	237:00:00	0	
Button fixing section	9	4	1353:00:00	48:00:00	5	
	97	87	113.5	82.0833333	8	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *EMPLOYEE* = Total Function Cost/Total Processed Cycles	158.8505747					

Simulation result after automation

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Washing Plant	20	20	0:00:00	320:00:00		14260
Sending Relevant Department to fix the problem	2	1	0:00:00	91:00:00		
Apparel go through Final finishing	6	0	1931:00:00	511:00:00		
Quality Check	9	8	0:00:00	703:00:00		
Sewing Line	30	30	0:00:00	540:00:00		
Isolating outputs to fit in different suitable operations	30	29	0:00:00	237:00:00		
Button fixing section	9	9	0:00:00	54:00:00		
	106	97	80.45833333	102.333333	0	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *ROBOT* = Total Function Cost/Total Processed Cycles	147.0103093					

Findings:

Although we have four bottleneck function areas that appeared in the first simulation, but we do not have the scope to automate them all. Isolating problematic apparels from fresh and sending them to relevant departments to fix the problems take much time but we cannot automate them with robots since human employee needs to check thoroughly under high illuminations and magnifying glass which a robot cannot do. Similar scenario with isolating outputs to fit in different operations. There is one function that can be automated is button fixing. The traditional way of button fixing is human employees fix buttons using machines that can be fully automated by robots. Therefore, the simulation was carried out in both ways, considering human employees executing all the process using modern technology and only button fixing area is fully automates.

If we simulate all steps with human employees, we find that processing functions do not receive all input within one cycle time. But if we can automate button fixing activity, we have more inputs and more processed units. Previously, within one cycle, processed output was **87 pcs**, after automating the button fixing it has increased by **10 units** to make **97 units**. Since more functions are processed in the same cycle time, therefore the cost is increased from **EUR 13820 to 14260**.

Per processes cost while handled by employees is around EUR 159 while handled by robots it is EUR 147.

4.9 Simulation result and process explanation of EPC Diagram of apparel final finishing

After apparels have accessories and button fixed it proceeds through final finishing. Final finishing starts with thread suction which is a final finishing of apparel to remove loose threads. Production employees do this with the suction machine. Next step is ironing, this step can be executed fully automatically but finishing is not as good as manual ironing therefore, manual ironing is preferred in Viyellatex. After that ironed apparels go through checking steps to find out apparels with stained and sewing defect. Apparels with sewing defect goes to sewing line and with stained go for washing. good apparels proceed to have accessories attached which are label, hangtag etc. Apparels are assorted to find apparels with perfectly attached accessories and not perfectly attached accessories. Improperly accessories attached apparels go to get fixed and properly accessories apparels move for poly packing and cartooning. Cartooning is done manually which could be fully automated. We have simulated having cartooning step automated and having the usual procedures, below simulation result has been found (See diagram in Appendix-03).

Simulation result having all process carried out typically

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Assorting	29	28	0:00:00	230:00:00	0	22340
Accessories attachment	29	29	0:00:00	290:00:00	0	
Cartoning	28	27	0:00:00	274:00:00	0	
Polypacking	28	28	0:00:00	280:00:00	0	
Ironing	30	30	0:00:00	270:00:00	0	
Metal Detection	29	29	0:00:00	174:00:00	0	
Thread Suction	30	30	0:00:00	240:00:00	0	
Isolating outputs to fit in different suitable operations	58	57	0:00:00	462:00:00	0	
	261	258	0	92.5	0	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *EMPLOYEE* = Total Function Cost/Total Processed Cycles	86.58914729					

Simulation result having cartooning process automated

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Assorting	29	28	0:00:00	230:00:00	0	20200
Accessories attachment	29	29	0:00:00	290:00:00	0	
Cartoning By Robotic Arms	28	28	0:00:00	112:00:00	0	
Polypacking	28	28	0:00:00	280:00:00	0	
Ironing	30	30	0:00:00	270:00:00	0	
Metal Detection	29	29	0:00:00	174:00:00	0	
Thread Suction	30	30	0:00:00	240:00:00	0	
Isolating outputs to fit in different suitable operations	58	57	0:00:00	462:00:00	0	
	261	259	0	85.75	0	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *ROBOT* = Total Function Cost/Total Processed Cycles	77.99227799					

Findings

Although bottlenecks are assorting, cartooning, and isolating outputs to fit in different suitable operations, we have the possibility only for the cartooning stage to automate. After automating the cartooning stage process function processed all units it received for processing while previously it was **27 out of 28**. Cartooning time and total cost have been declined significantly from **EUR 22340 to 20200**.

Per processes cost while handled by employees is around EUR 86 while handled by robots it is EUR 78.

4.10 Simulation result and process explanation of EPC Diagram of Postproduction process and transport planning to send goods to final customer within accepted time

In case of transportation management is handled manually, the transport planner receives a load request, he needs to print the email, log into a website to find available loads, log into the company's transportation management system to enter the details, then confirm the request by retyping all the details into the load websites. After typing the parameter gets the best load information from the transportation company. The next step is to lock up the best rate after researching other available options. Finally, send the schedule and location information to the driver, confirms with the customer, and input the new load information into the scheduling system. This one task consumes nearly 20 hours of the dispatcher's time.

On the contrary, if the whole transportation process by RPA bots executes as follows. RPA bots track if the material is ready for shipment, for packed material bots enter load pickup parameters and extract the result. It automatically picks the best load and returns the schedule and location information to the driver and confirms the customer details about shipment immediately. if a pickup request comes in via email or hard-working robots can extract those shipment details, log jobs in scheduling systems, and provides pick time in customer or carrier portals. Following are the simulation result for transportation planning managed entirely by human employees and automating some steps (See diagram in Appendix-03).

Shipment handled entirely by human employees

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Rate Lookups	30	29	0:00:00	525:00:00	0	*6643*
Picking packed goods and leaving WH towards Customer/Seaport for export	29	29	0:00:00	0:00:00	0	
Load Capture	30	29	0:00:00	583:00:00	0	
Confirming Pickup via agreed lane and conditions	29	29	0:00:00	145:00:00	0	
Shipment Scheduling and Tracking	30	30	0:00:00	600:00:00	0	
	148	*146*	*0*	*77.208333*	*0*	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *EMPLOYEE* = Total Function Cost/Total Processed Cycles	*45.5*					

Some steps of shipment handled by RPA bots

Name	Process folders received	Process folders processed	Dynamic wait time sum	Processing time sum	Process folders in dynamic wait state	Function costs
Rate Lookups	30	29	0:00:00	119:00:00	0	*3395*
Picking packed goods and leaving WH towards Customer/Seaport for export	29	29	0:00:00	0:00:00	0	
Load Capture	30	29	0:00:00	119:00:00	0	
Confirming Pickup via agreed lane and conditions	29	29	0:00:00	145:00:00	0	
Shipment Scheduling and Tracking	30	30	0:00:00	600:00:00	0	
	148	*146*	*0*	*40.958333*	*0*	
PER PROCESS COST CALCULATIONS BY EMPLOYEE						
Per process cost while handled by *ROBOT* = Total Function Cost/Total Processed Cycles	*23.25342466*					

Findings

The above finding shows that receiving packed unit and processed unit for shipment is same for both the procedure and there is no dynamic wait time because human employee also uses software to handle transportation management but total processing time and total cost have been reduced significantly by using software bots.

Per processes cost while handled by employees is around EUR 45 while handled by robots it is EUR 23.

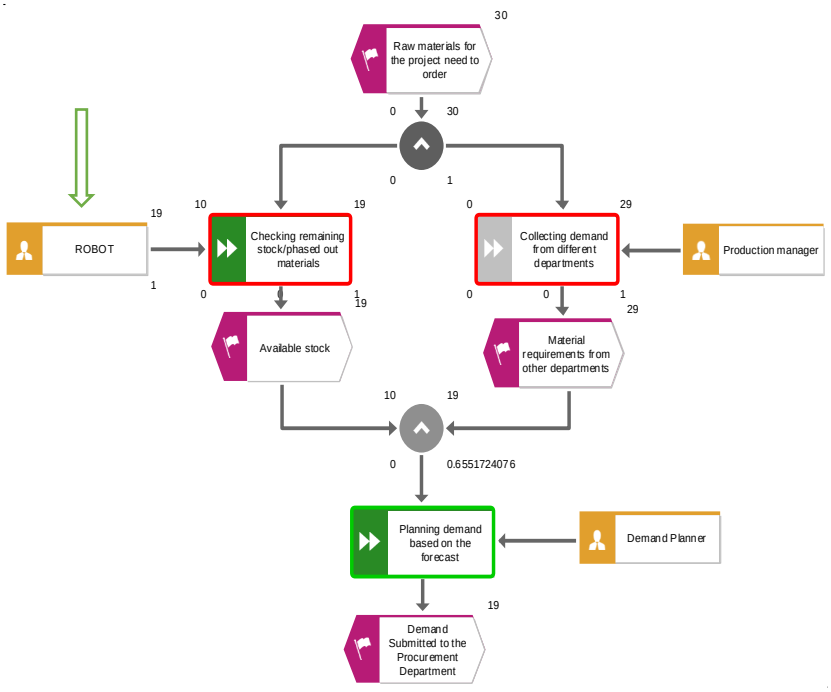
CHAPTER: 5 RECOMMENDATIONS

5.1 Controlling and planning inventory by applying RPA

Inventory management is one of the crucial parts of SCM automation in the RMG sector. This is necessary to track how much inventory available in the production area and how much in the warehouse. Insufficient inventory hinders production that results in some production lines to stop, likewise, a surplus in inventory increases storing cost and occupy space in the warehouse where finished product supposed to be stored.

The robot can be used to detect out-of-stock items, errors in labels, or missing labels. Robots can check inventory much efficiently and cheaply than human employees. As soon as an error is found robots convey this information to the store clerk immediately.

Although raw materials are ordered based on the product requirement from buyers, but some items are continuously required for RMG production such as Pin, Poly, Carton, Plastic clip, M-Clip, Butterfly, Neck board, Backboard, Collar insert, Collar bone, so on. Machine learning (ML) combined with Artificial intelligence (AI) can predict consumer demand which can be forecasted based on previous sales data. Accessories could be ordered based on season, for example, accessories for winter jackets and warm clothes in October and for woven shirts and nit T-shirts in March. Using AI, RPA analyses the different external factors that affect consumer demand, designs, and models to optimize inventory management. Besides, robots will inform purchasers to place purchase orders if the inventory level drops below a certain level. [23]



Robotic process automation diagram for better demand planning and inventory tracking

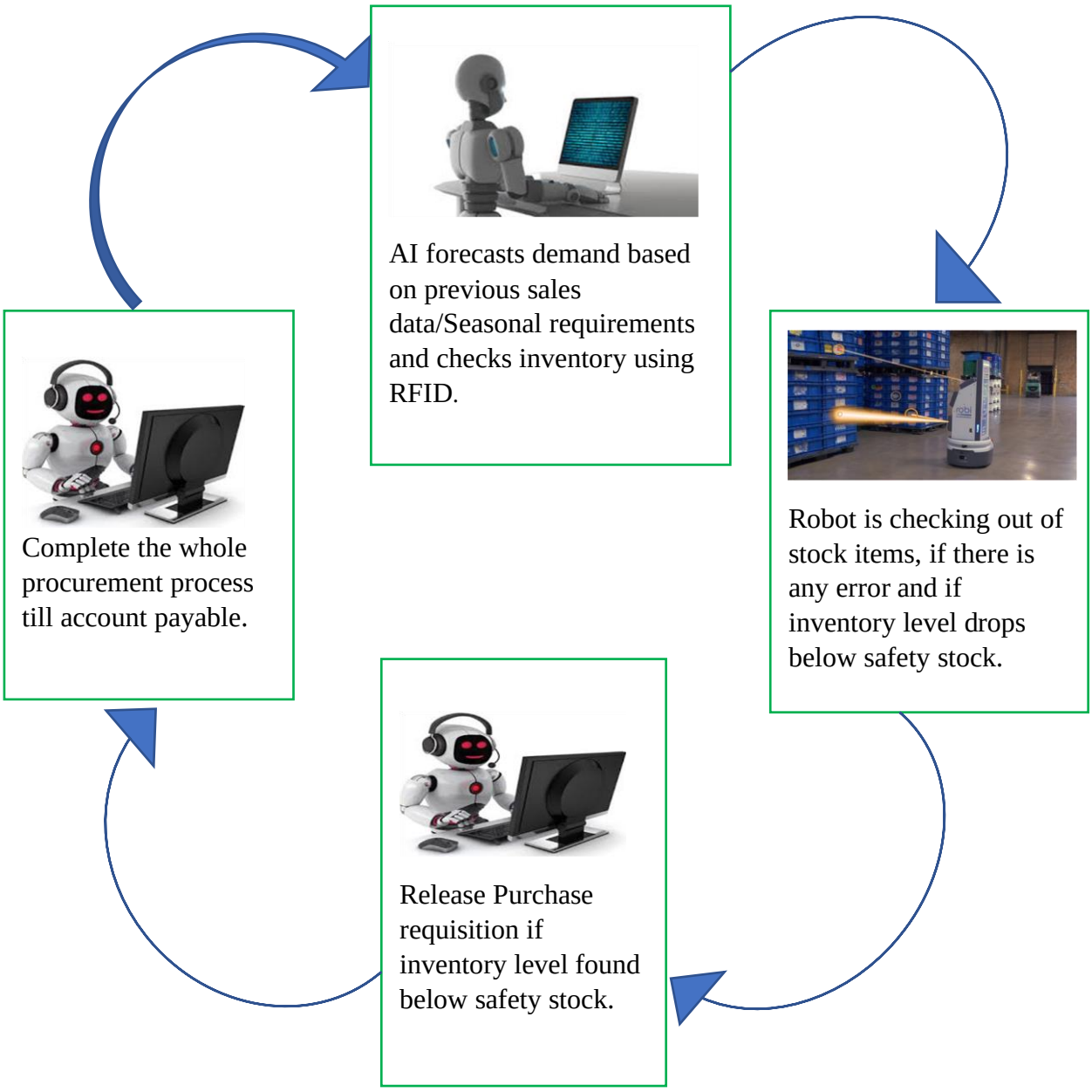


Figure 4. 4: Automated Demand Planning and Inventory Tracking Diagram (Source: Made by Author)

5.2 Automation in Purchasing

Although this is one process, but it covers lots of steps and tasks in that process. Amongst the tasks listed below, some can be automated but some cannot be.

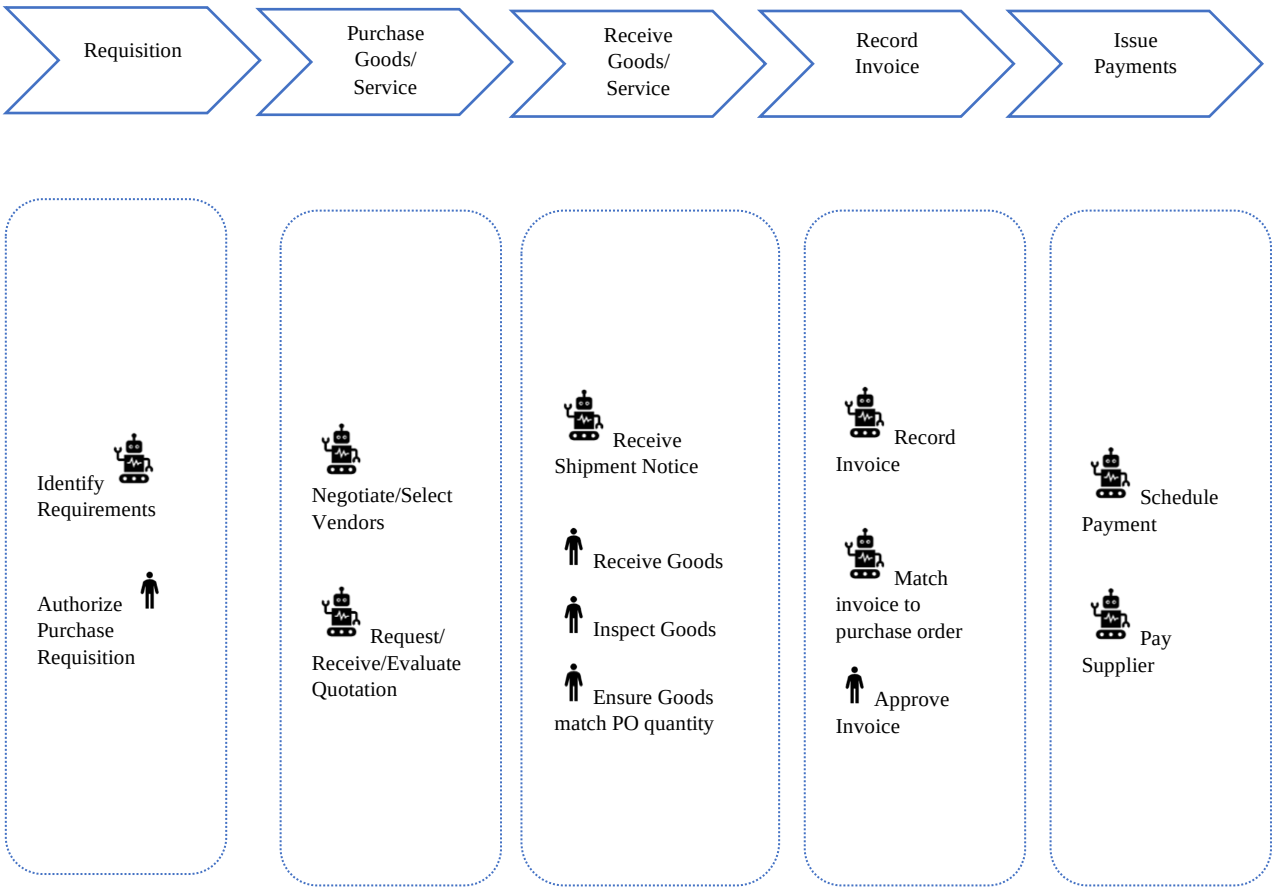


Figure 4. 5: Automation in Purchasing (Source: Made by Author)

Brief description of transforming purchase request into purchase order:

A robot logs in to SAP and searches for open purchase requisition. After identifying open purchase requisition, it checks the parameters for the organization, confirms the receipts, collects further receipt data on the portal, reads the documents which are attached to the purchase request, fulfills the purchase order, then saves the order, attaches the document, the whole process is done. It usually takes around 15 minutes for a human being but only 3 minutes for a robot. [25]

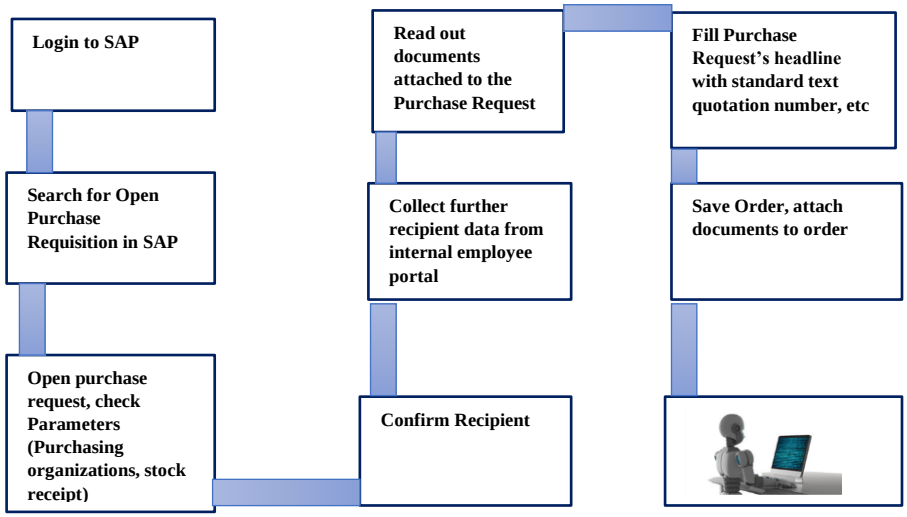


Figure 4. 6: Swimlane Diagram of Purchasing Automation (Source: Made by Author)

5.3 Automation in invoice management:

The first task of the process is to automatically locate and download the PDF invoices from dedicated email addresses where all invoices are sent by suppliers. After downloading invoices from emails RPA shorts out the emails based on suppliers, for instance, saving emails for YKK zippers, VIYELLATEX accessories, BEST BUTTONS, to the specific folder defined for future trace out. Soon after the invoices have been shorted out, RPA sends emails to the account manager and purchaser notifying them that some invoices have arrived. Once the purchaser receives the emails, the purchaser can approve the invoices by sending emails to the account manager. The PDF invoices go through another process from where the robots read and extract specific information. The information that has been extracted by the robots can be configured and modified according to the preference of used cases. In this used case we have chosen to capture the following information. The invoice number, invoice description, invoice issue date, invoice due date, quantity, and total amount due. In this task robot, transfers extracted information into the relevant section of the financial accounting applications. [25]

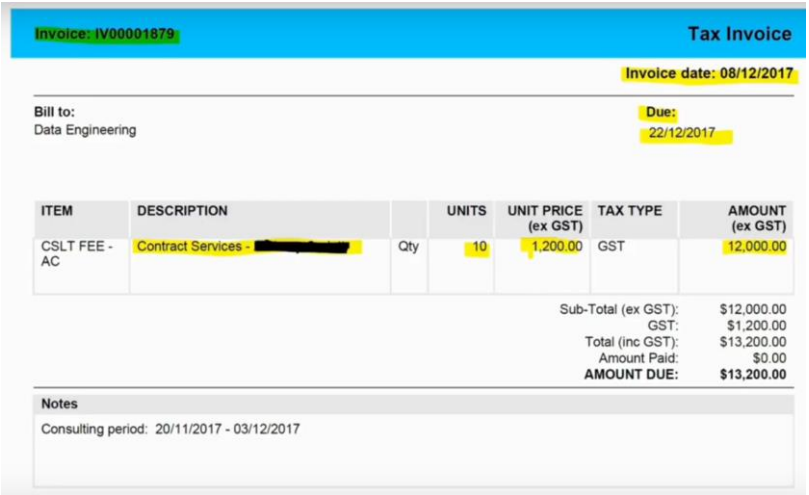


Figure 4. 7: Invoice Automation Sample by RPA bots [32]

In this task robot transfer extracted information into the relevant section of the financial accounting applications.

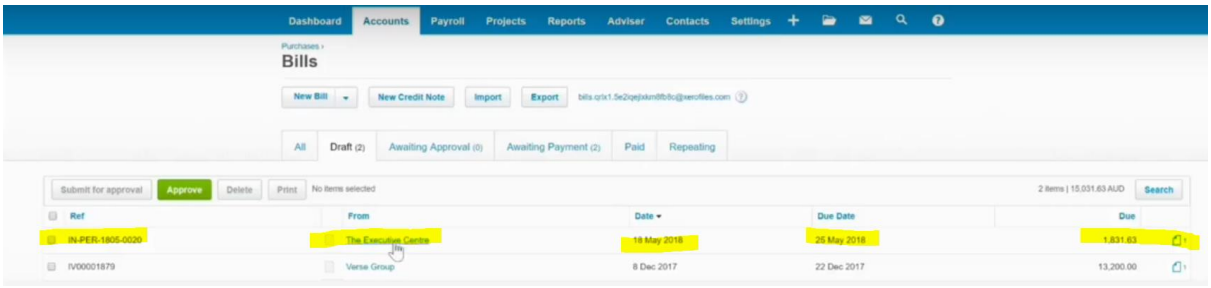


Figure 4. 8: Invoice Automation Sample by RPA bots [32]

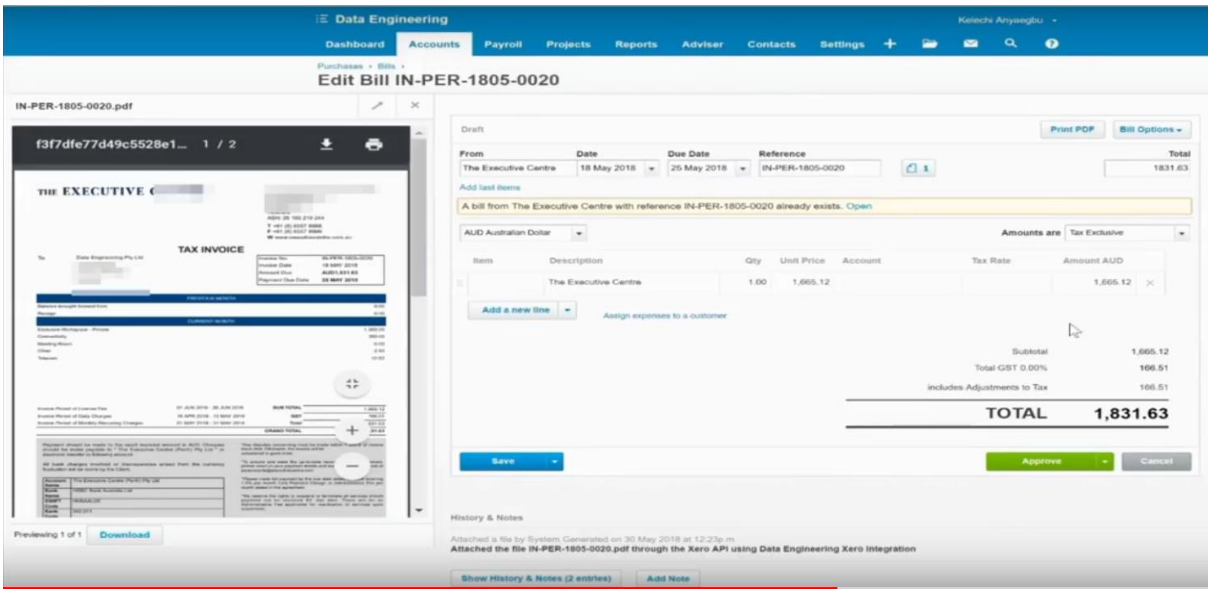


Figure 4. 9: Invoice Automation Sample by RPA bots [32]

As soon as the invoices have been saved as a draft in the accounting system, an email notification is sent to the account manager informing him that invoices are waiting for approval. If the account manager has received an approval email from the purchaser, he can then proceed with selecting the account type before clicking the approval button and activating the payroll. During this task, the robot will move individual PDF invoices to a folder in online document storage as below picture which is named as processed invoices located on share point online. [32]

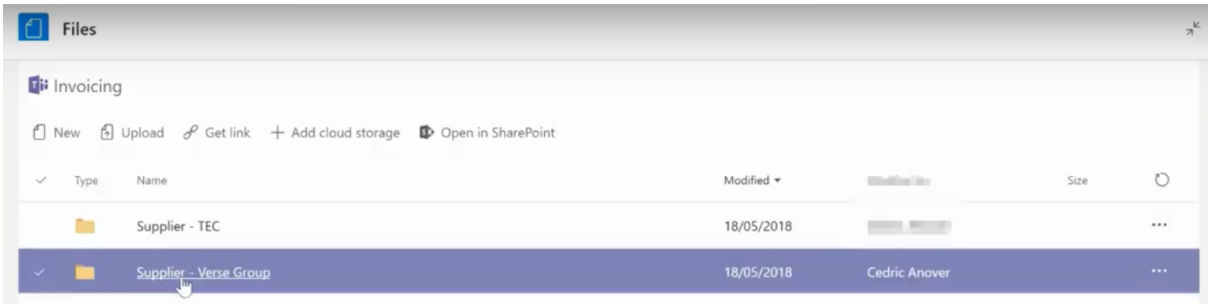


Figure 4. 10: Invoice Automation Sample by RPA bots [32]

Users can see which invoices were successfully processed by the robots. In this final task, the RPA robot publishes all the earlier retrieved invoice data to a dashboard to enable the account payable manager to stay updated in the flow of invoices into the business. [32]

Figure 4. 11: Invoice Automation Sample by RPA bots [32]

Consequently, invoice automation expedites the buying process of the raw materials that enable the RMG manufacturer to fine-tune the production to keep the LT.

Proposed automated invoice management swim lane diagram

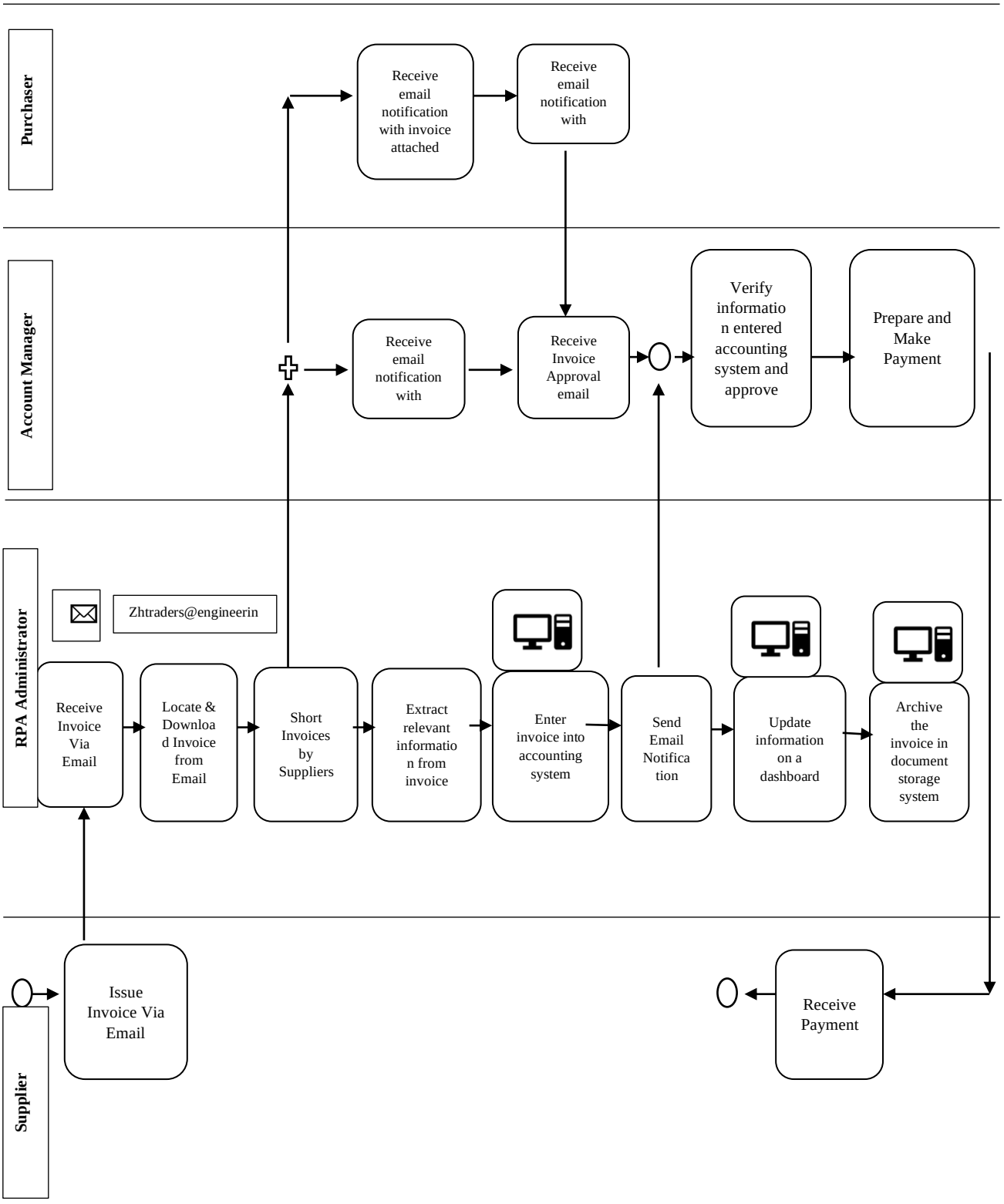


Figure 4. 12: Swimlane Diagram of Invoice Automation by RPA bots [Source: Made by Author]

5.4 Proposed automation in production procedures:

Fabric & Accessories Racking: Accessories and fabrics are racked before entering them into the sewing line. Racking is done by human employees which can be automated by robotic arms as below.

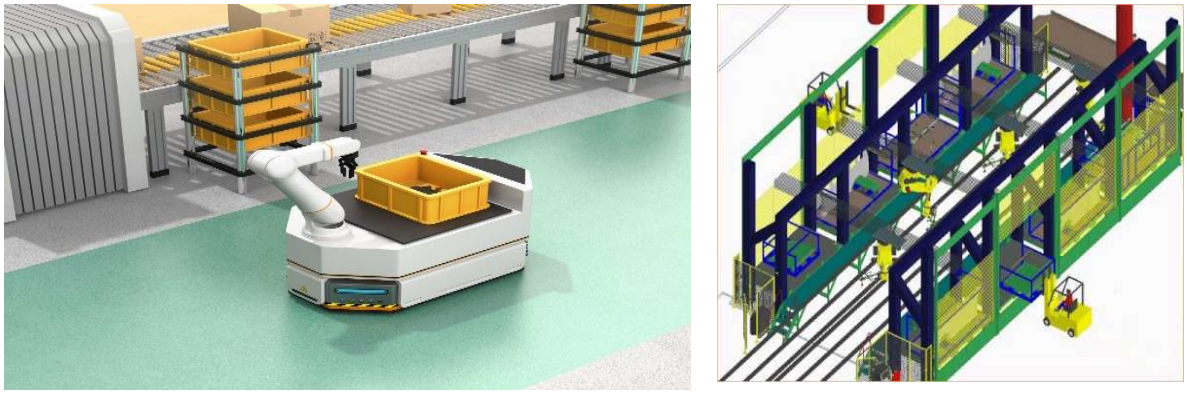


Figure 4. 13: Racking by Robotic Arms [42]

Robotic Button Fixing: Buttons and other accessories could be Fixed automatically by the below robotic automation system if the investment is worthy.

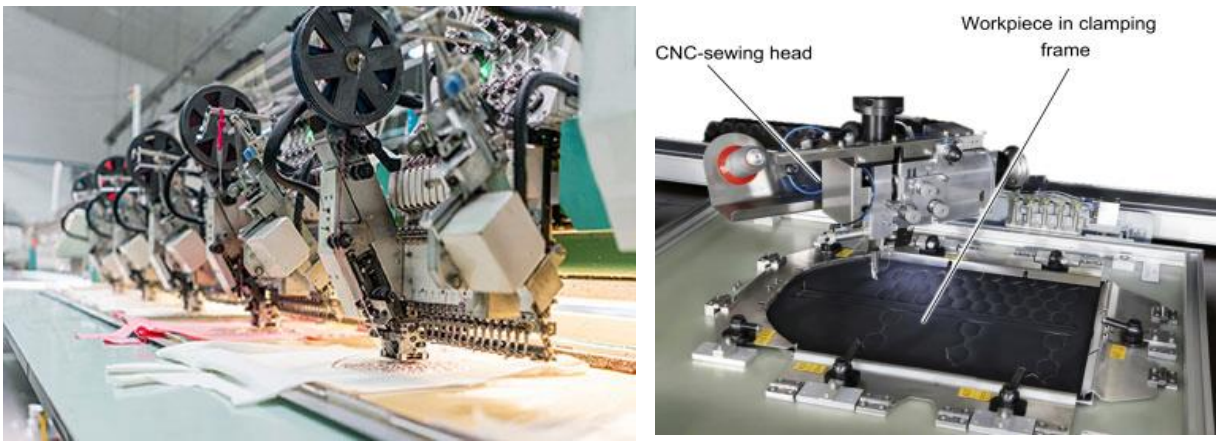


Figure 4. 14: Button Fixing by Robots [43]

Robotic Cutting system: This process is semi-automated. Currently fabrics are being shaped with machines which can be made no-touch process with the help of robots as below.

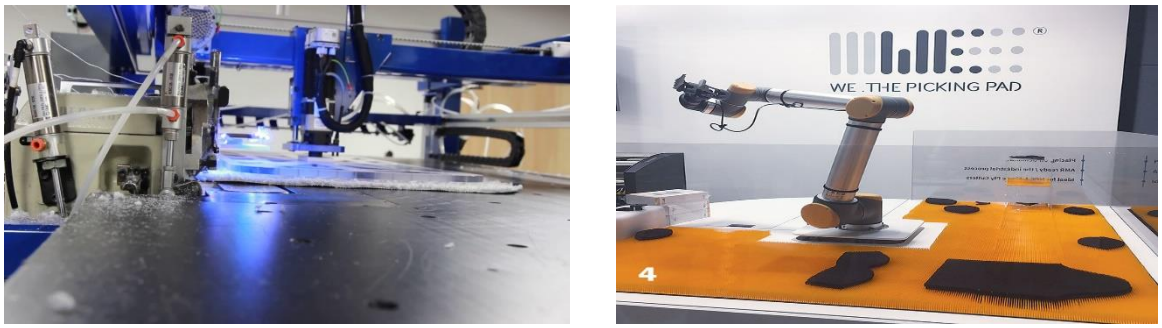


Figure 4. 15: Robotic Cutting System [43]

Robotic packing system

Poly wrapping and packing are being done by human employees which also could be made more automate by installing robotic packing machine as below.

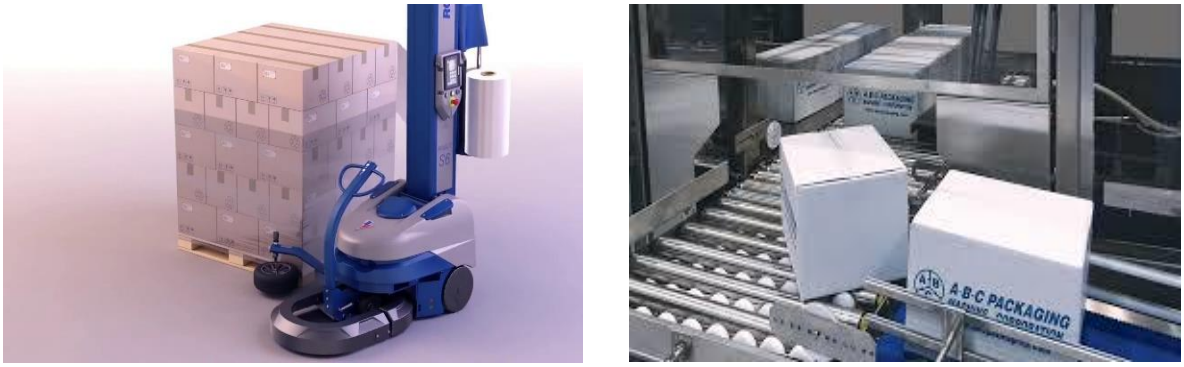


Figure 4. 16: Robotic Packing System [43]

5.5 RPA to improve logistics operation in the RMG industry:

Managing lead time is the most important task for any RMG company. Loading shipment on time is being hugely impacted by improper transportation management.

These tasks could be done by process automation within a very short time implementing the following steps

- Automatization shipment scheduling and Tracking with RPA
- Picking up arrived request
- Processing request and load data
- Automatically picking the best load
- Return information to driver, TMS, and customer

A trucker delivers a load and has empty space in the truck. A load request or similar tasks can be performed by clicking a button or can be scheduled to get triggered by another application, for instance, when a load is

delivered, the robot enters the load pickup parameters and search for results, once the result is available it delivers the result within a few seconds according to the specified parameters then automatically picks the best load to transport. Afterward, the robot returns the schedule and location information to the drivers, Simultaneously, confirms with the customer, and inputs the new load information into the scheduling system. if a pickup request comes in via email, RPA bots can extract those shipment details, log jobs in scheduling systems, and provides pickup time to customer or carrier portals. [18]

Proposed logistics automation with RPA

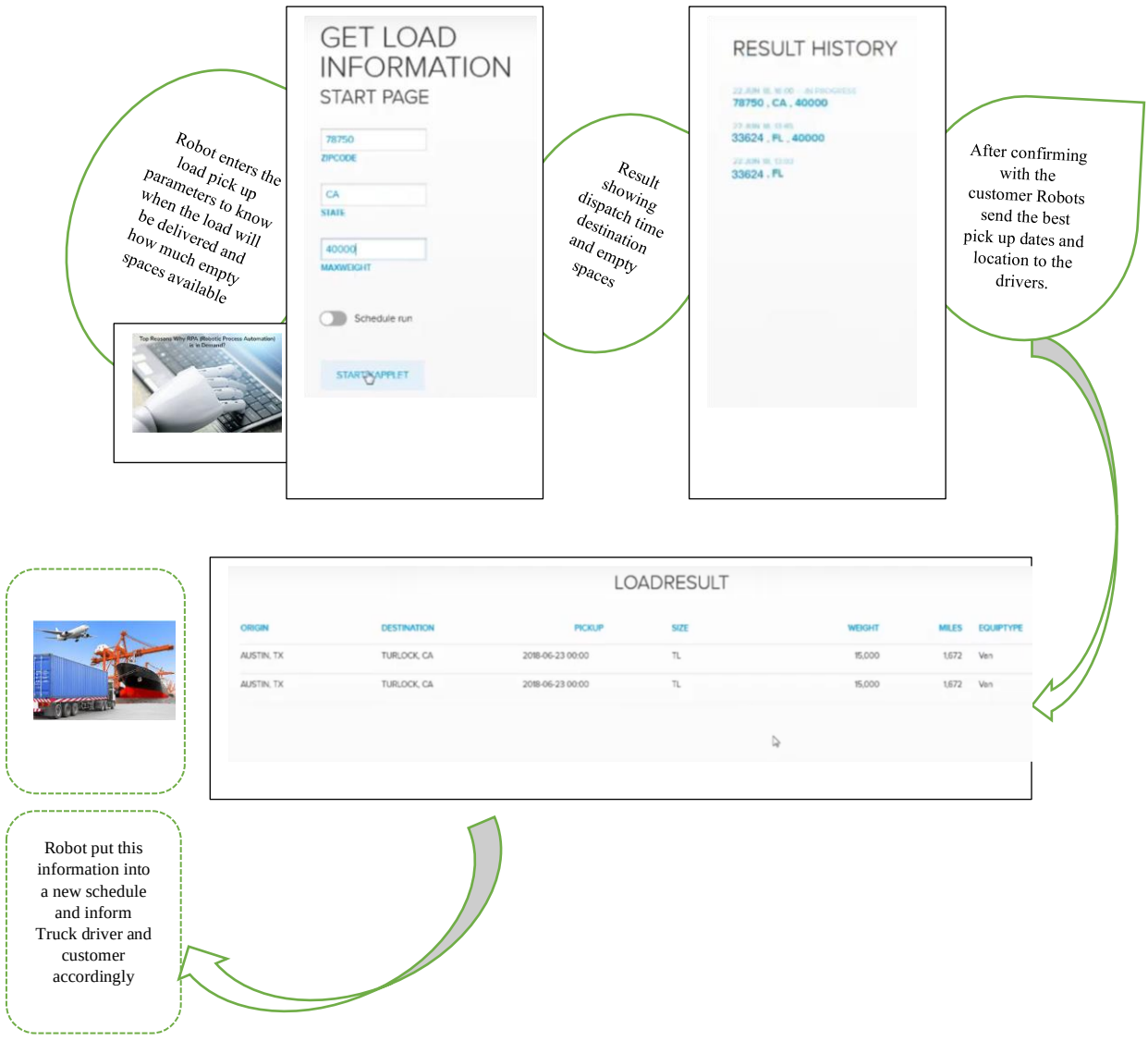


Figure 4. 17: Proposed logistics Automation [Source by Author]

CHAPTER 6- CONCLUSION

The outcomes of the analysis will be concluded in this chapter to precisely outline the scope of automation in the potential areas of the supply chain of the readymade garment industry in Bangladesh. Simulation carried out by ARIS Architect and designer 10. Based on the data got from Viyellatex will be presented concisely to figure out the manual and inefficiently managed steps. In the first place, the simulation was done having cost, processing time as input while they are handled manually, and bottlenecks were detected. After that, the simulation was done replacing manual processes with robots, which appeared as bottlenecks in the previous step. Cost and time required for RPA bots were derived from data available in online resources. Eventually, Automation possibilities to have efficiency in supply chain and production in Viyellatex, as well as other RMG firms have been recommended.

Research Question 1: Identifying which areas of the supply chain in the RMG sector of Bangladesh are managed manually and if there is the possibility to automate them.

The supply chain and production procedures of the Ready-made garment industry of Bangladesh are not fully automated and are still in the growth stage. There are some areas such as inventory tracking, demand planning, invoice management, and transportation planning, which are yet not automated, not even considered as feasible to automate, since they are being handled by human employees cheaply. The lead time, which is the most important challenge for RMG industries are influenced significantly by these steps. A lot of accessories belongs to a large number of vendors are needed within the stipulated time. If purchase requisition, purchase order, and vendor selection are not automated, it causes not to have all inbounds available within the expected time. Similarly, if shipment and transportation are not properly planned, it leads to missing the expected shipment date which results in huge demurrage. According to the data, provide by Viyellatex Ltd, the mentioned steps are being handled by human employees through ERP software. Employees track and plan inventory, when inventory level drops below safety stock, they create purchase requisitions and place purchase orders in ERP. Additionally, vendor selection, GR posting after goods receipt is also done manually. There is a possibility of automation in the procurement process by including RPA bots in association with currently used ERP software. There is a back to back LC (letter of credit) against master LC which is used to purchase required raw materials for production. If invoices are not paid on time, suppliers stop delivering raw materials, which results in the inbound rollout to stop leading not to maintain the LT. Invoices are also made ready for payment manually, which has the possibility to be automated by RPA bots. As Viyellatex and most other RMG manufacturing firms are exporting their apparel to famous international brands, to maintain standard quality, their production activities are being maintained mostly following the latest technology. Therefore, there is not that much possibility to automate production procedures except in some areas such as racking, cutting, button fixing, and packing.

Research Question 2: How to automate previously identified areas of the supply chain in the RMG sector of Bangladesh by removing human intervention to make them accurate and efficient.

Although there is not that much possibility to automate production processed, there is a huge opportunity to automate pre-production and post-production activities. In preproduction activities, there are some prospective areas to automate by RPA bots, such as inventory tracking system, sending automatic notifications to release purchase requisition, automatically turning purchase requisition to purchase order, loading all vendor data in ERP, and selecting specific vendors for specific materials at a pre-defined price, eventually making sales agreement. some activities. Likewise, many steps, for instance, locating invoices, downloading invoice of invoice management can be automated. To check how much efficiency will be increased after replacing manual processes with RPA bots, the simulation was conducted. Having input as cost, processing time, and other perimeters if both invoice management and procurement process are handled manually after that simulation was conducted by replacing some manual steps with RPA bots. Significant improvement in efficiency was found after replacing the manually handled process with RPA bots. For instance, dynamic wait time and processing time decreased remarkably, more batches were received and processed by the process functions extensively, moreover, cost decreased radically. There is also some bottleneck process found in production activities which are semi-automated such as cutting, button fixing, fabric racking, accessories racking, and packing. These steps are also simulated, and the efficiency level increased soberly. The cost of connecting RPA bots with current ERP software/user portal/website is quite acceptable. For regular maintenance and employee training, there might be a routing cost which is also reasonable. Nevertheless, the cost of full automation in the production process for instance fully automated cutting, button fixing, robotic racking arm, and packing machines might require massive investment but, in the long run, the compensation will be much worthy. Hence, LT will be reduced to the expected level, consequently, more work order will be offered, and customer loyalty will be achieved accordingly.

CHAPTER 7 – SUMMARY

This research intends to detect inefficiently managed steps in the supply chain of the RMG industry in Bangladesh based on the data available from Viyellatex Ltd and if there is any possibility to automate them if they are managed manually. The research questions have been carried out to have a complete understanding of how supply chain and production are being executed and if Robotic Process Management can make those steps automated, as well as, more efficient. After identifying the potential areas of the supply chain in Viyellatex, which have been managed manually for years, the author has simulated considering them as automated and analysed the results. Based on the result, a conclusion is drawn, needed actions are proposed in the recommendation chapter.

This study comprises a bibliometric analysis of the resources depicted in the literature review derived from recent research on supply chain and robotic process automation. The most recently updated tools recommended by experts were used to simulate and result were analysed through a solid systematic way. Additionally, the empirical data used in this thesis were collected through questionnaires, interviews, annual reports, and journals following the qualitative approach. Comments from responsible persons working in the relevant departments of Viyellatex have helped immensely to conclude. Quantitative data analysis and deductive approach lead towards the result that enabled to set corrective actions. Among the classified bottleneck steps, preproduction and postproduction are the most important areas to implement automation since most of the production steps are either automated or semi-automated. In preproduction steps, particularly inventory tracking, raw material procurement processes, invoice clearing processes are the most important sections to integrate their ERP operation with RPA bots. In the postproduction process, rate lockup, obtaining instant load information, informing drivers about load information can be automated along with currently used ERP. In the production process, to solve manual processes appeared as bottlenecks, automatic fabric cutting robots, robotic arms for racking both the fabrics and accessories, robotic button fixing, and automatic packing machines could be included if fixed cost is affordable.

Eventually, the outcomes of this research could be implemented in the supply chain of Viyellatex Ltd as well as other RMG firms. This research can provide a thorough idea about robotic processing automation in the supply chain, specifically, for those firms which need to procure various types of raw materials frequently and must clear invoices as soon as receiving the raw materials not to have inbound rollout interrupted. Additionally, in this study, the author has suggested automation in some steps of demand and transport planning to shorten the lead time. Several comprehensive corrective actions were recommended via figures to make implementation easier and successful. To have an efficiently functioning system that uses RPA, master data needs to be updated regularly, bugs need to be checked and fixed. Since RPA bots are not that much popular in the RMG industry, employees should be provided with all types of training required to understand automation and get things done by RPA. The objective of robotic process automation is not to replace human employees with robots rather to train them to get things done more efficiently by robots. Hence, to replace those vacancies, which had been manged by older employees before their retirements but not interesting to the young people.

CHAPTER 8 – SUMMARY (In Estonian)

Selle uurimustöö eesmärk on leida Bangladeshi RMG tööstuse tarneahela ebaefektiivselt lahendatud töövõtted, toetudes Viyellatex Ltd poolt avaldatud andmetele. Samuti leida võimalusi manuaalselt tehtavate tööde automatiseerimiseks. Uurimustöö küsimused on koostatud mõistmaks tarneahela ja tootmise tööd ning kas kasutades *Robotic Process Management´*i (RPM) on võimalik tööd automatiseerida ning efektiivsemaks muuta. Pärast aastaid manuaalselt tehtud tööde identifitseerimist Viyellatexi tarneahelas, simuleeris autor samu töid automaatsetena ning analüüsis saadud tulemusi. Leitud tulemused viisid järeldusteni, mille põhjal tehtud parendusettepanekud on esitatud soovituste peatükis.

Käesolev uurimustöö sisaldab bibliomeetrilist analüüsi tarneahela ja protsesside robotitega automatiseerimise uuringuid käsitlevatest hiljutistest materjalidest, mis on kirjeldatud kasutatud kirjanduses. Simuleerimiseks on kasutatud ekspertide poolt soovitatud kaasaegseid lahendusi ning tulemused on süsteemselt analüüsitud. Lisaks on kogutud emipiirilisi andmeid läbi küsimustike, intervjuude, aastaaruannete ning päevikute kasutades kvalitatiivseid meetodeid. Viyellatexi vastutavate töötajate kommentaarid on aidanud teha järeldusi. Kvantitatiivsete andmete analüüs ja välistav lähenemine võimaldasid teha parendamiseks vajalikke samme. Tuvastatud kitsaskohtade hulgas on kõige olulisemad tootmisele eelnevad ja järgnevad protsessid, sest tootmine ise on juba kas osaliselt või täielikult automatiseeritud.

Tootmisele eelnevatest etappidest, kus ettevõtte ressursside planeerimisse (ERP) tuleks integreerida RPA robotid, on oluliseimad laoseis, toormaterjali hankeprotsess ja raamatupidamine. Tootmisele järgnevate protsesside puhul saab kasutada olemasolevaid ERP-i võtteid ning automatiseerimist kas hindade külmutamiseks, reaalajas ülevaate saamiseks kaubalaadimisest või selle info edastamiseks autojuhtidele. Lahendamaks tootmises kitsaskohtadena näivaid manuaalseid protsesse saaks kasutusele võtta automatiseeritud kangalõikamise ja nööbiõmblemise roboteid ning robotkäsi kangaste ja aksessuaaride liigutamiseks, lisaks automatiseeritud pakkimismasinaid. Seda kõike juhul, kui fikseeritud kulu on taskukohane.

Kokkuvõtteks, antud uurimustöö järeldusi saab kasutada Viyellatex Ltd ja teiste RMG ettevõtete tarneahelas. Käesolev uurimustöö annab põhjaliku ülevaate tarneahela protsesside robotautomatiseerimisest. Seda eelkõige ettevõtetele, kes tegelevad tihti toormaterjalihankega ning peavad kiiresti tasuma arved, et tarned ei oleks häiritud. Lisaks annab autor soovitusi vähendamaks transpordiga seonduvat ajakulu läbi automatiseerimise. Mitmed sisulised soovitused on antud numbriliselt, et aidata kaasa lihtsale ning edukale kasutuselevõtule. Efektiivselt RPA-d kasutava süsteemi eeldusteks on pidevalt uuendatud põhiandmed ning vigade otsimine ja parandamine. Kuna RPA robotid ei ole RMG tööstuses levinud, siis tuleb pakkuda töötajatele erinevaid koolitusi mõistmaks automatiseerimise ning RPA põhimõtteid. RPA idee ei ole töötajate asendamine robotitega, vaid pigem õpetamine, kuidas roboteid kasutades efektiivsust tõsta. Seeläbi saaks asendada vabad töökohad, mis varasemalt olid hõivatud vanemate töötajatega, kes on jäänud pensionile, kuid millest uued töötajad ei ole huvitatud.

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Appendix-1

Questionnaires:

(1) What type of ERP SW is used and what types of activities are managed with that ERP?

(2) How do you check how much inventory is available, how much going to be expired?

(3) How procurement department get informed if inventory level drops below safety stock?

(4) How purchase requisitions and purchase orders are created?

(5) How vendors are selected and how replacement/claims are initiated?

(6) What is the procedure of GR posting after receiving materials from vendor?

(7) How do you procure material if listed vendor in SAP cannot meet the required delivery date?

(8) How invoices are received, downloaded, extracted relevant information and group based on customer?

(9) What happened if GR quantity and quote qty do not match?
Who approved invoices which should proceed for payment and how customer get paid?

(10) What is the apparel production steps and how they are executed?

(11) What happened if inhouse fabrics do not meet required criteria?

(12) Are there any steps in fabric preparation which are not fully automated?

(13) Are there any steps in accessories preparation which are not fully automated?

(14) Through what processes accessories and fabrics are connected to make complete apparel?

(15) Are there any steps in apparel final finishing which are not fully automated?

(16) How goods are made ready for shipment?

(17) How shipment is planned, and transportation arranged?

(18) How shipment rate is locked, and load information is derived?

(19) How much time and cost are required for one batch processing in preproduction process?

(20) How much time and cost are required for one batch production in different stage of production?

(21) How much time and cost are required to have shipment and transport planning done?

Identifying preproduction cost and processing time for one cycle

How many of different types of inventory can be checked within one full day?

How many purchase requisition and purchase order could be released in one full day?

How much time require to find vendors for one specific material which do not have vendor fixed in ERP?

Identifying postproduction cost and processing time for one cycle

How much time and cost does it required for rate lock up and finding suitable load information for RFS goods of 125 cubic meters?

How much time does it take to send load information to vehicle driver and shipment notification to the customer?

Appendix-2

Time and Cost required in different steps of preproduction, production and postproduction steps while handling both by human employee and by robots

Cost of the processes managed by RPA bots, robotic arms, robotic cutting machine, robotic racking and robotic packing have been calculated by disbursing fixed cost and maintaining cost for 10 years period. Labour cost is in euro based on per hour cost per employee according to Bangladeshi standard.

Process title	**Total cost when carried out by Human Employee for one batch production (Calculated in EUR)**	**Total Cost When carried out by RPA Bots for one batch production**	**Total time required Execute by Human Employee for one batch production**	**Total time required when Execute by RPA Bots within 24 hours for one batch production**
Checking inventory level/phased out/expired	50	20	40 hours	16 hours
Releasing purchase requisition	70	11	30 hours	4 hours
Preparing purchase order	70	15	40 hours	8 hours
Vendor selection	80	20	50 hours	10 hours
PO placing to vendor & generating corresponding Sales order	70	12	40 hours	5 hours
Locating & Downloading invoices	60	8	40 hours	5 hours
Shorting invoices by suppliers	50	8	40 hours	5 hours
Extracting relevant information from invoice	50	8	40 hours	5 hours
Sending email notification	50	8	40 hours	5 hours

Updating information on a dashboard	50	8	40 hours	5 hours
Fabric racking	12	12	40 hours	8 hours
Racking scissor fabric	300	50	85 hours	12 hours
Cutting fabric to shape to required apparel	1000	150	100 hours	20 hours
Accessories racking	300	50	85 hours	12 hours
Button and other accessories fixing	500	100	100 hours	15 hours
Packing	200	50	40 hours	12 hours
Rate lookups	40	8	40 hours	8 hours
Load capture	40	8	40 hours	8 hours
Sending load notification to vehicle driver	30	5	20 hours	2 hours
Sending shipment notification to the customer	50	8	40 hours	8 hours

Appendix-3

4.3 EPC Diagram of Demand Planning

All steps of demand planning done by Human Employee, Value added activities in Green border, Non-value added but must done activities in Yellow border, and waste accumulator or related to store areas are in Red border

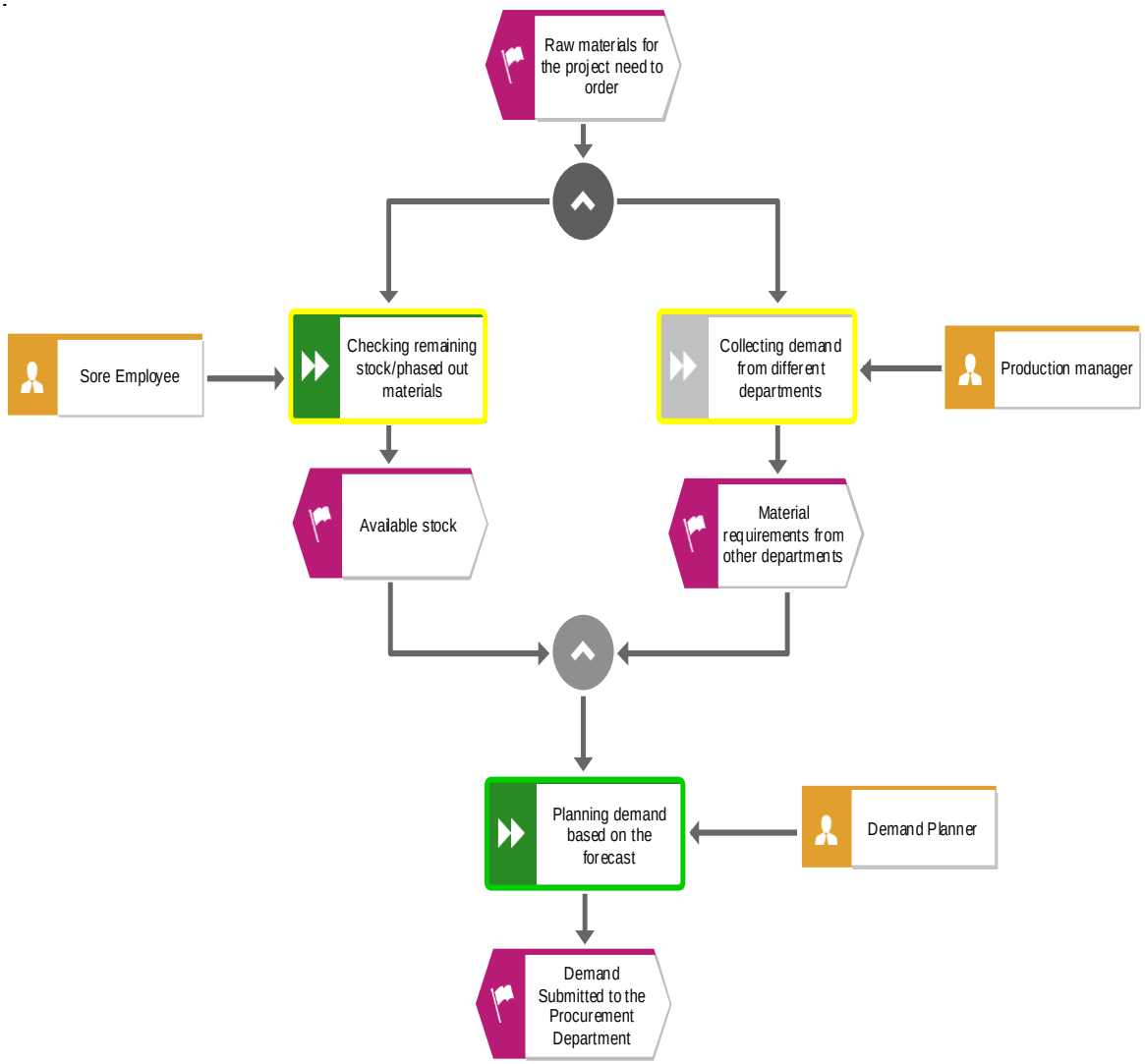

Figure 4. 18: EPC Diagram of Demand Planning by Human Employee (Source: Made by Author)

Some steps of demand planning done by Robots, Value added activities in Green border, Non-value added but must done activities in Yellow border, and waste accumulator or related to store areas are in Red border,

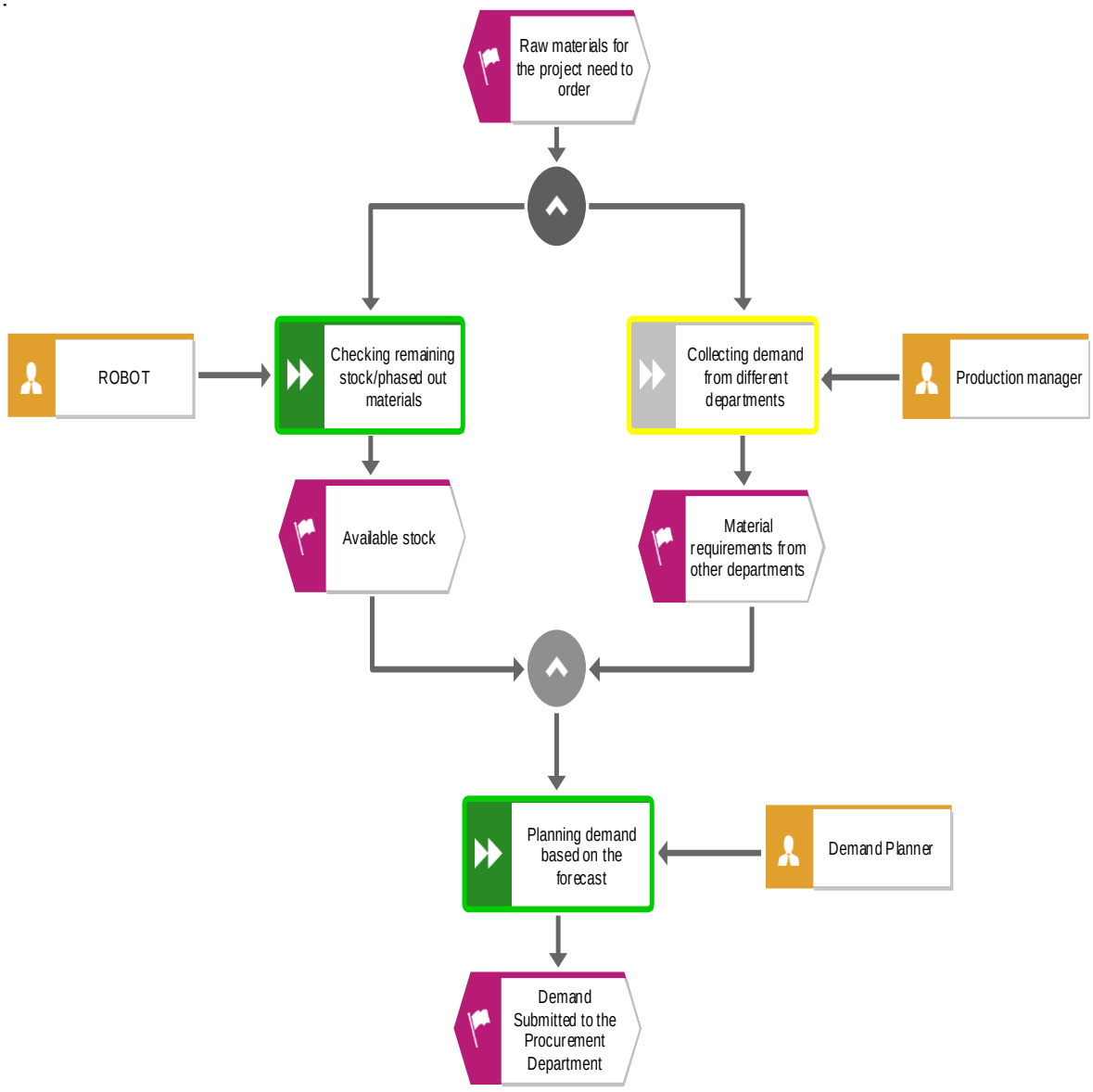

Figure 4. 19: EPC Diagram of Demand Planning one step by Robots (Source: Made by Author)

4.4 Basic EPC structure of raw material procurement

Raw Material Procurement by Human Employee, Value added activities in Green border, Non-value added but must done activities in Yellow border, and waste accumulator or related to store areas are in Red border,

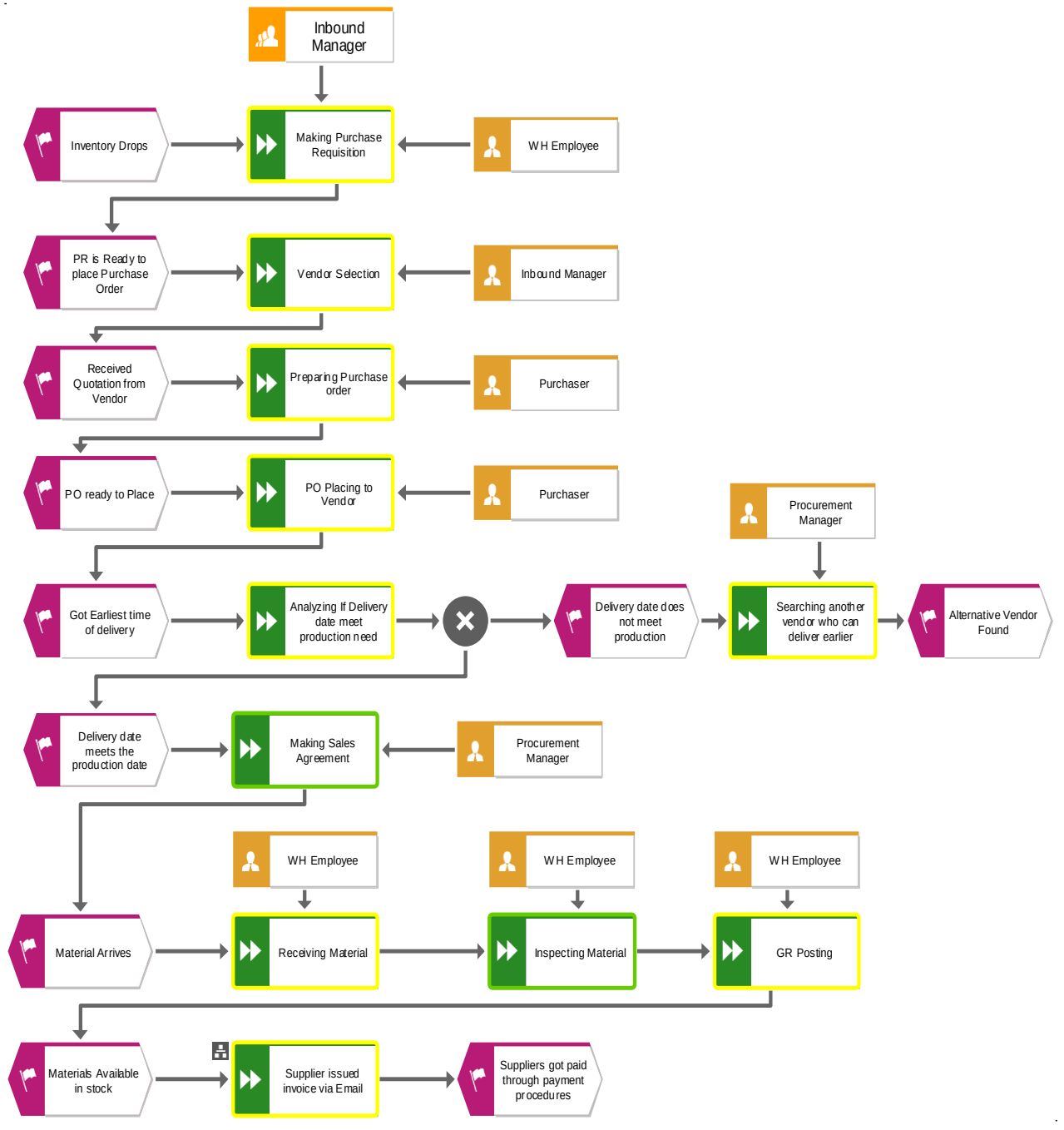

Figure 4. 20: EPC Diagram of Raw material procurement by human employee (Source: Made by Author)

Raw Material Procurement *some steps replaced by RPA*, Value added activities in Green border, Non-value added but must done activities in Yellow border, and waste accumulator or related to store areas are in Red border

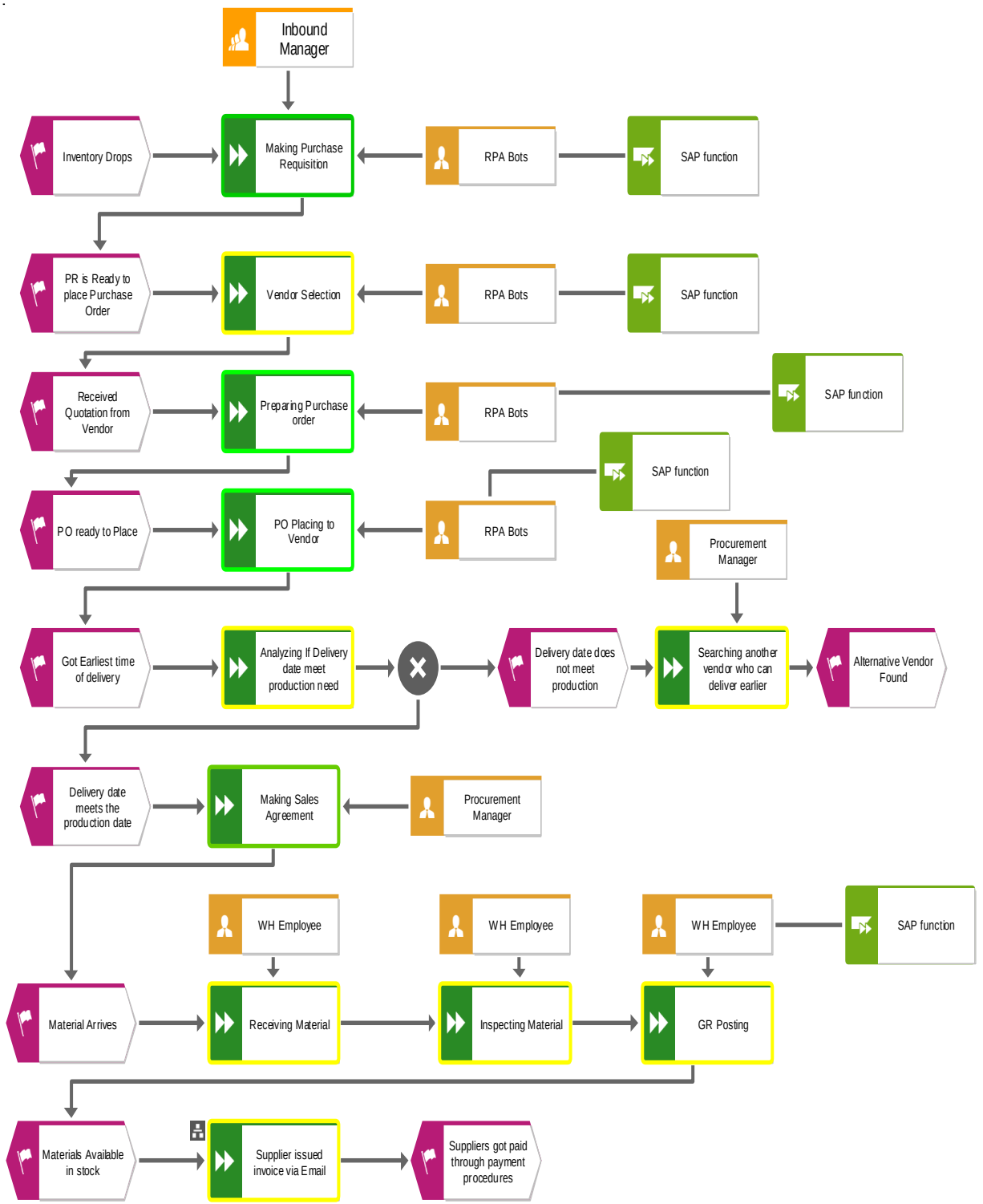

Figure 4. 21: EPC Diagram of Raw material procurement some steps by Robots (Source: Made by Author)

4.5 EPC Invoice processing model by both human employees and some steps with RPA bots

Invoice Processing by Human Employee, Value added activities in Green border, Non-value added but must done activities in Yellow border, and waste accumulator or related to store areas are in Red border Red border,

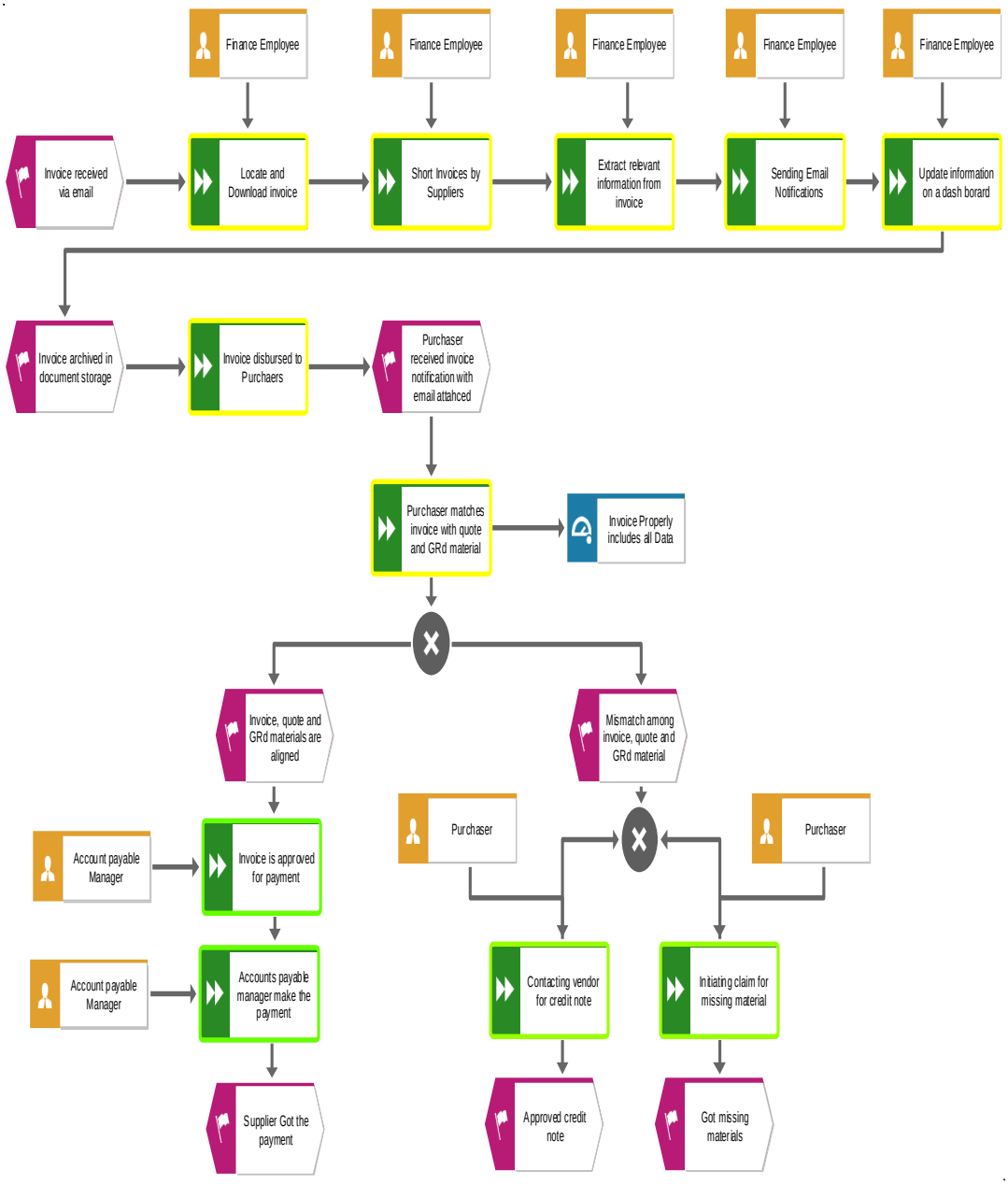

Figure 4. 22: EPC Diagram of Invoice Processing by Human Employee (Source: Made by Author)

Some steps of Invoice processed by RPA bots, Value added activities in Green border, Non-value added but must done activities in Yellow border, waste accumulator or related to storage area in Red border,

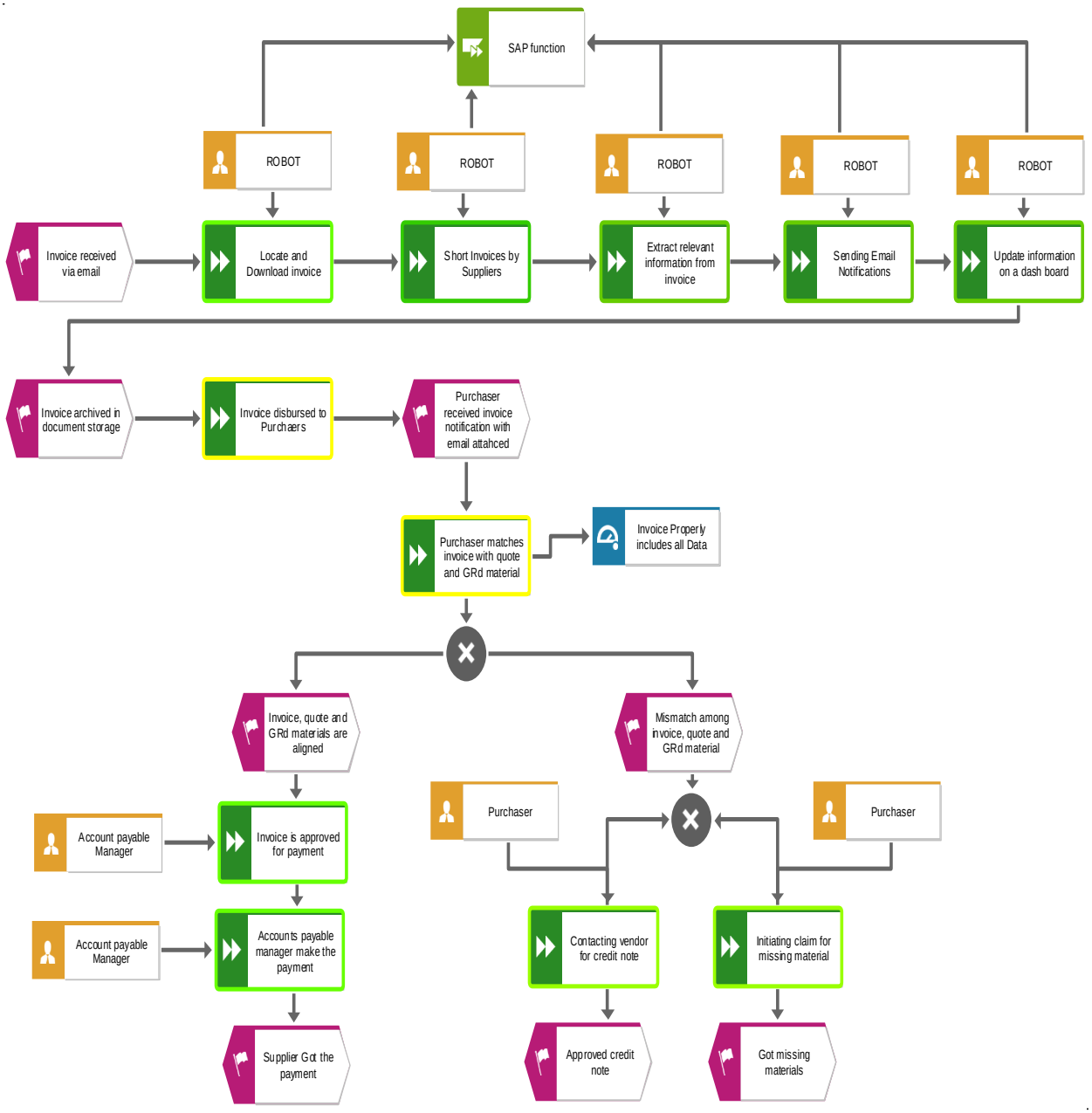

Figure 4. 23: EPC Diagram of Invoice Processing Some Steps by Robots (Source: Made by Author)

4.6 EPC diagram of fabric preparation model by both human employees and some steps with robots.

Fabric Processing by Human Employee using automatic machines, Value added activities in Green border, Non-value added but must done activities in Yellow border, and waste accumulator or related to store areas are in Red border

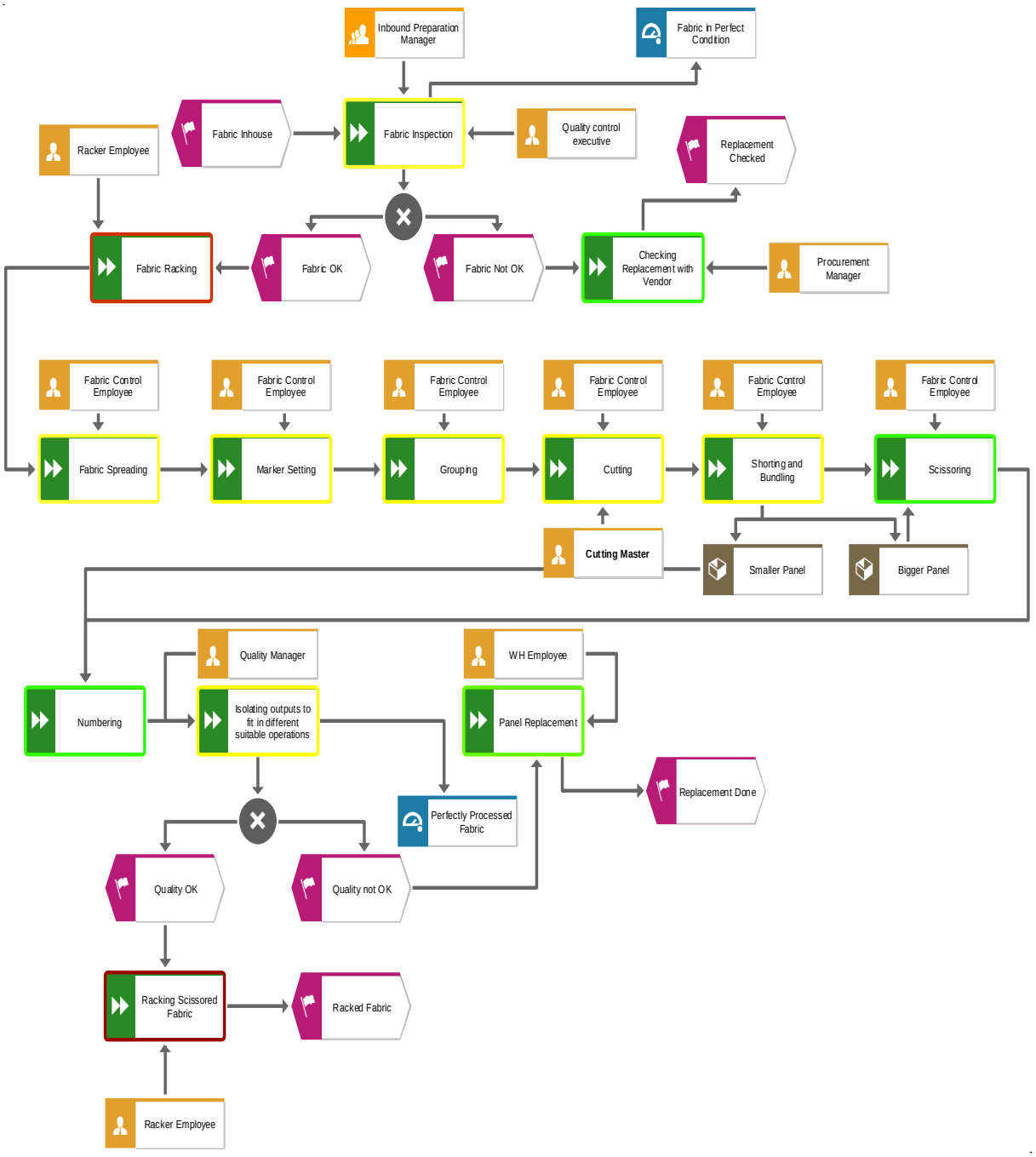

Figure 4. 24: EPC Diagram of Fabric Processing by Human Employee (Source: Made by Author)

Some steps Fabric Preparation by Robots, Value added activities in Green border, Non-value added but must done activities in Yellow border, and waste accumulator or related to store areas are in Red border,

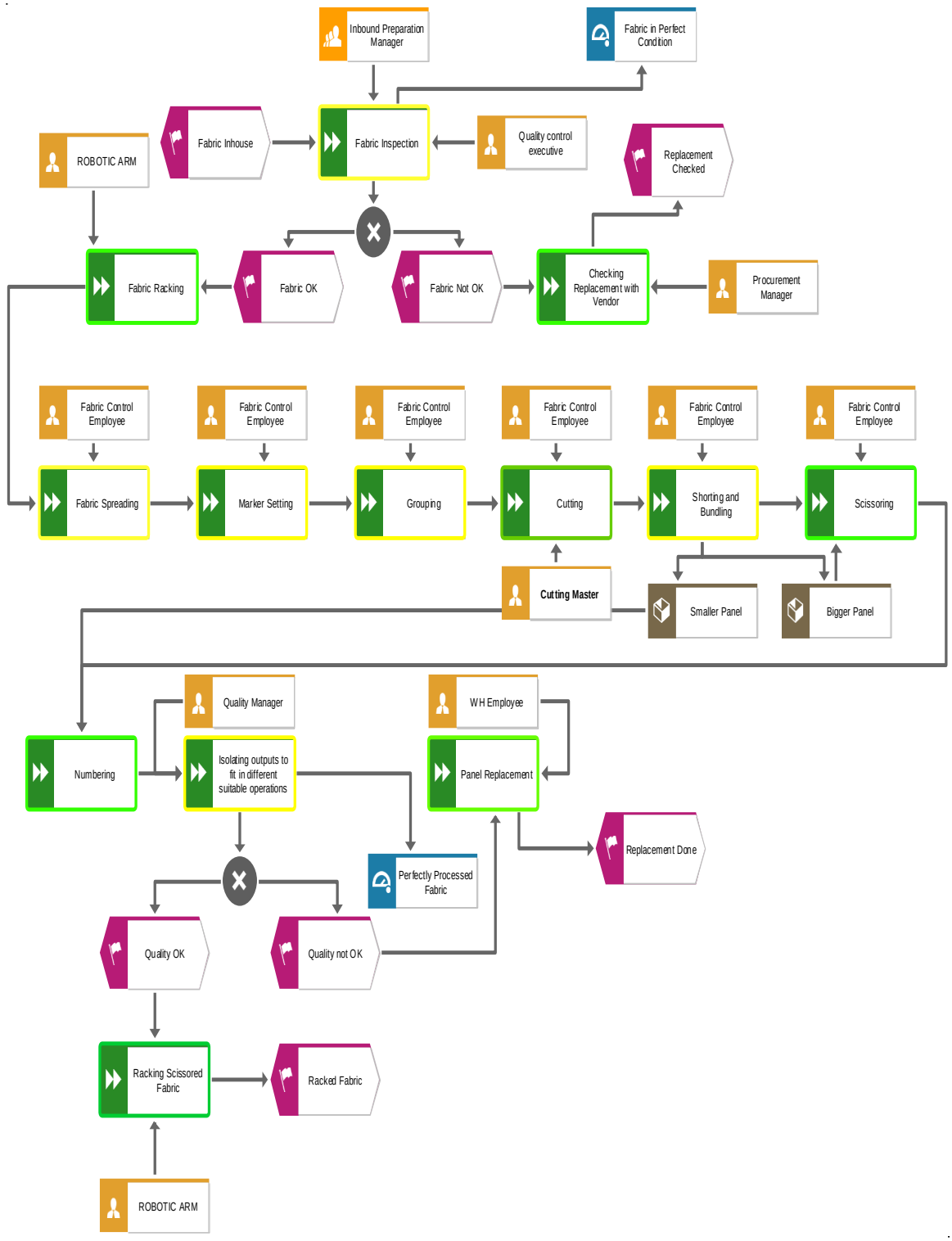

Figure 4. 25: EPC Diagram of Fabric Processing Some Steps by Robots (Source: Made by Author)

4.7 EPC Diagram of Accessories preparation for apparel production

Simulation result when all steps are managed by employee with automatic machines, Value added activities in Green border, Non-value added but must done activities in Yellow border, and waste accumulator or related to store areas are in Red border,

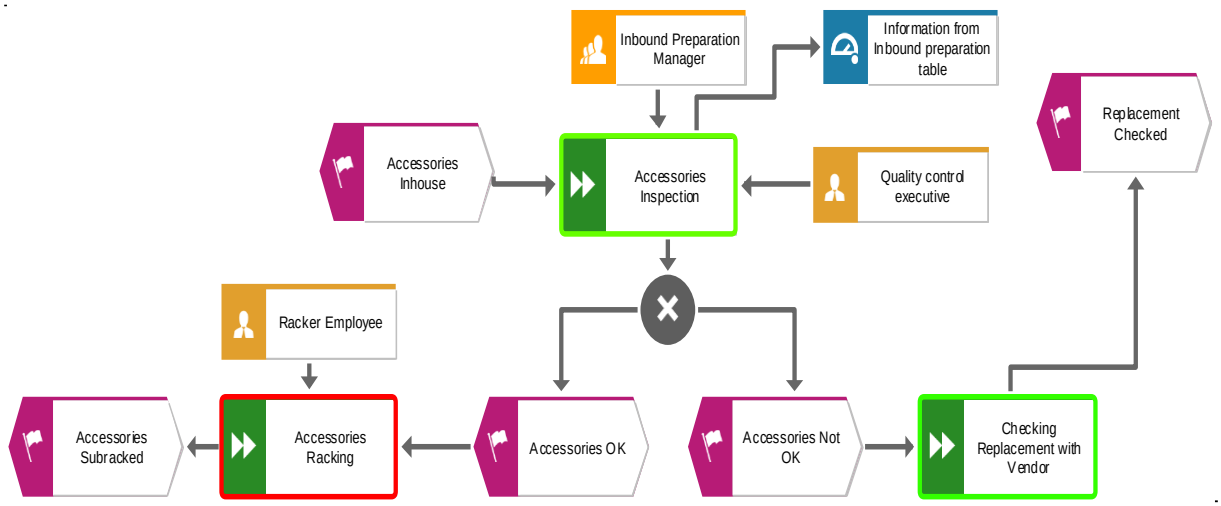

Figure 4. 26: EPC Diagram of Accessories Preparation by Human Employee (Source: Made by Author)

Simulation result after one step is fully automated, Value added activities in Green border, Non-value added but must done activities in Yellow border, waste accumulator or related to store areas are in Red border,

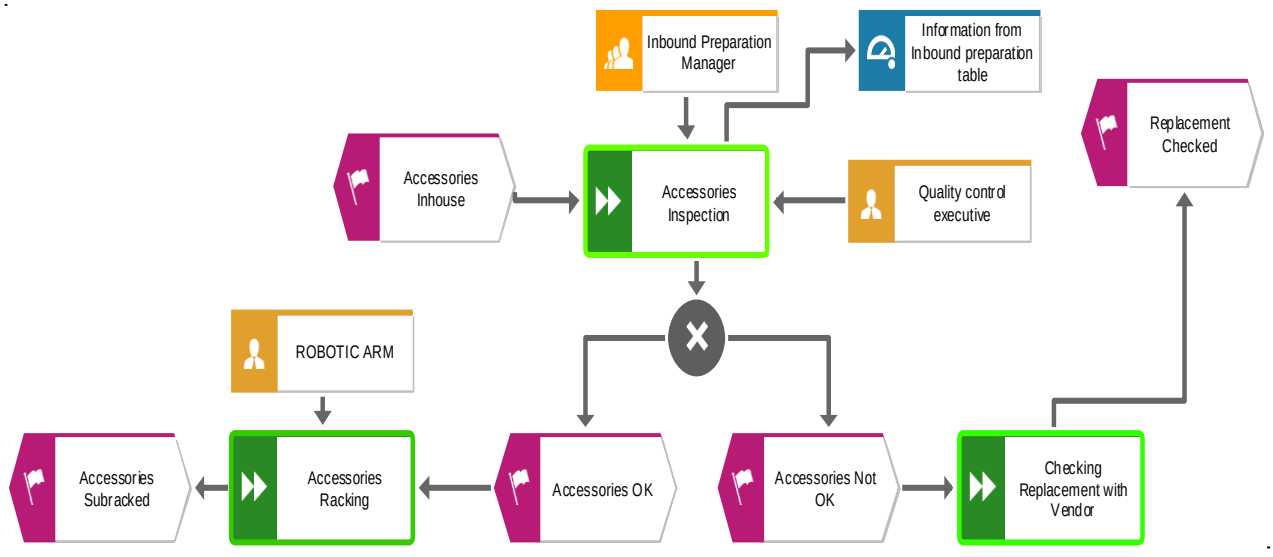

Figure 4. 27: EPC Diagram of Accessories Preparation Some Steps by Robots (Source: Made by Author)

4.8 EPC diagram of fabric and accessories connection

Simulation result when all steps are managed by employee with automatic machines, Value added activities in Green border, Non-value added but must done activities in Yellow border, and waste accumulator or related to store areas are in Red border,

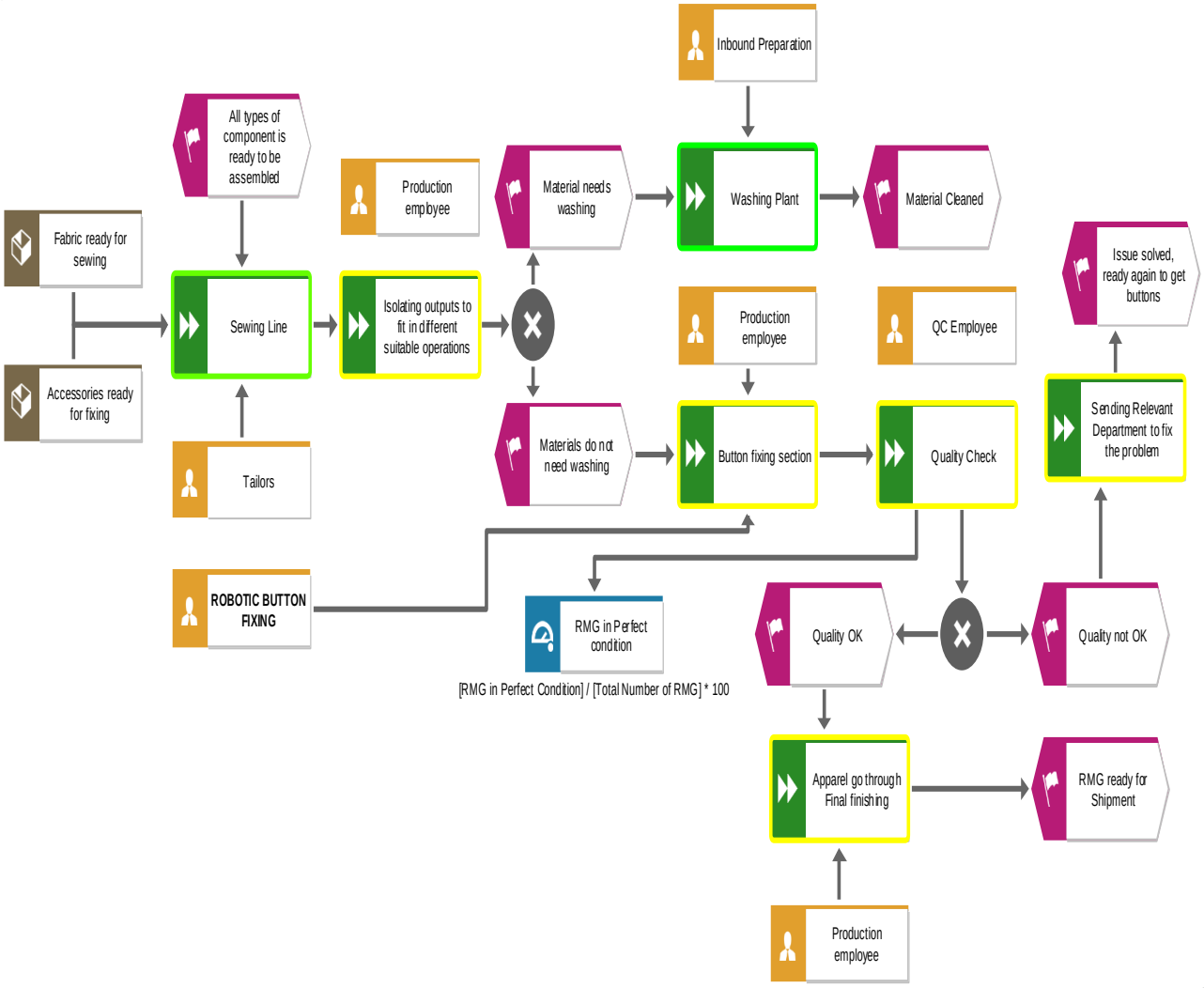

Figure 4. 28: EPC Diagram of Accessories & Fabric Connection by Human Employees (Source: Made by Author)

Simulation result after one step is fully automated, Value added activities in Green border, Non-value added but must done activities in Yellow border, waste accumulator or related to store areas are in Red border,

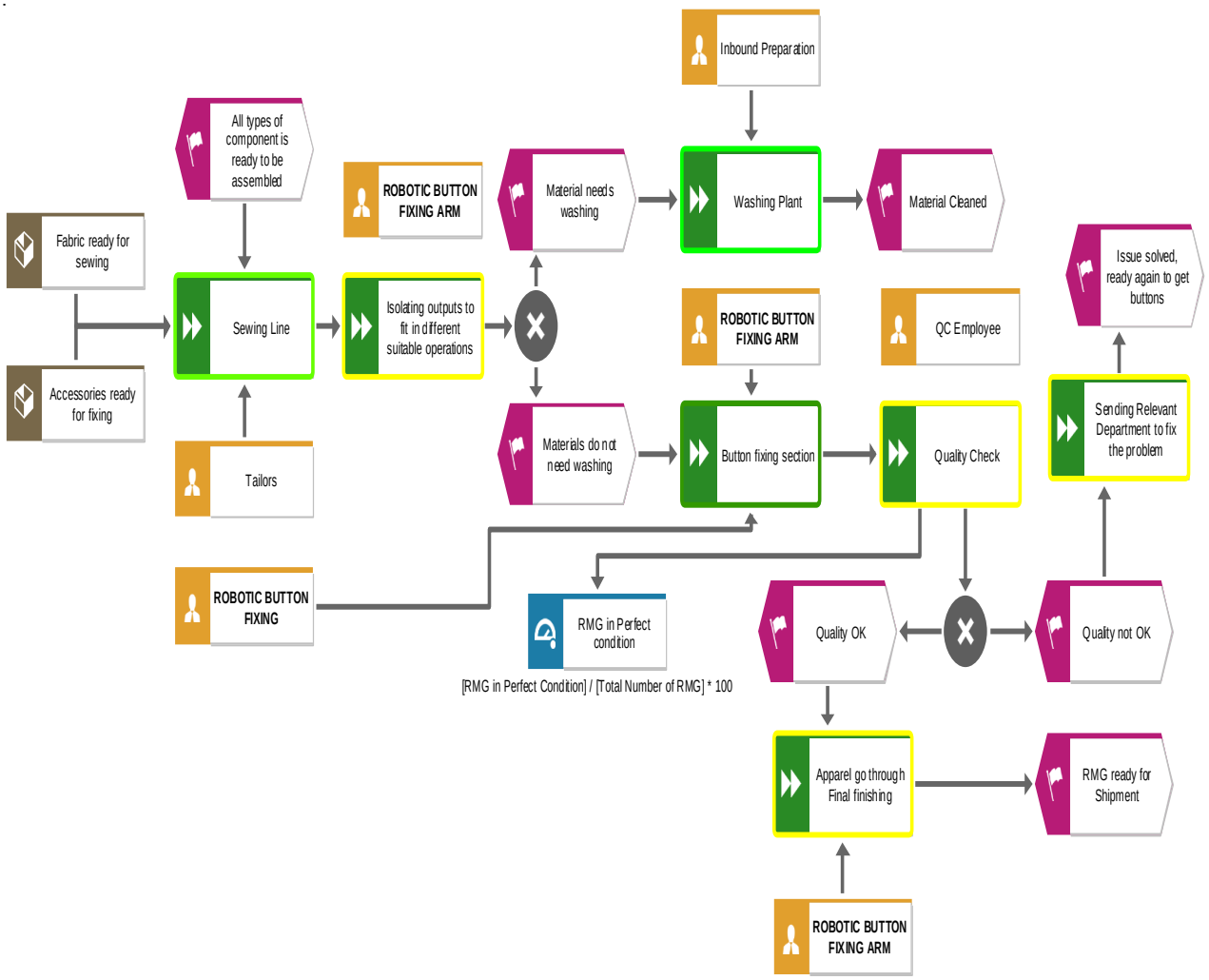

Figure 4. 29: EPC Diagram of Accessories & Fabric Connection Some steps by Robots (Source: Made by Author)

4.9 EPC Diagram of apparel final finishing

Simulation result when all steps are managed by employee with automatic machines, Value added activities in Green border, Non-value added but must done activities in Yellow border, waste accumulator or related to store areas are in Red border,

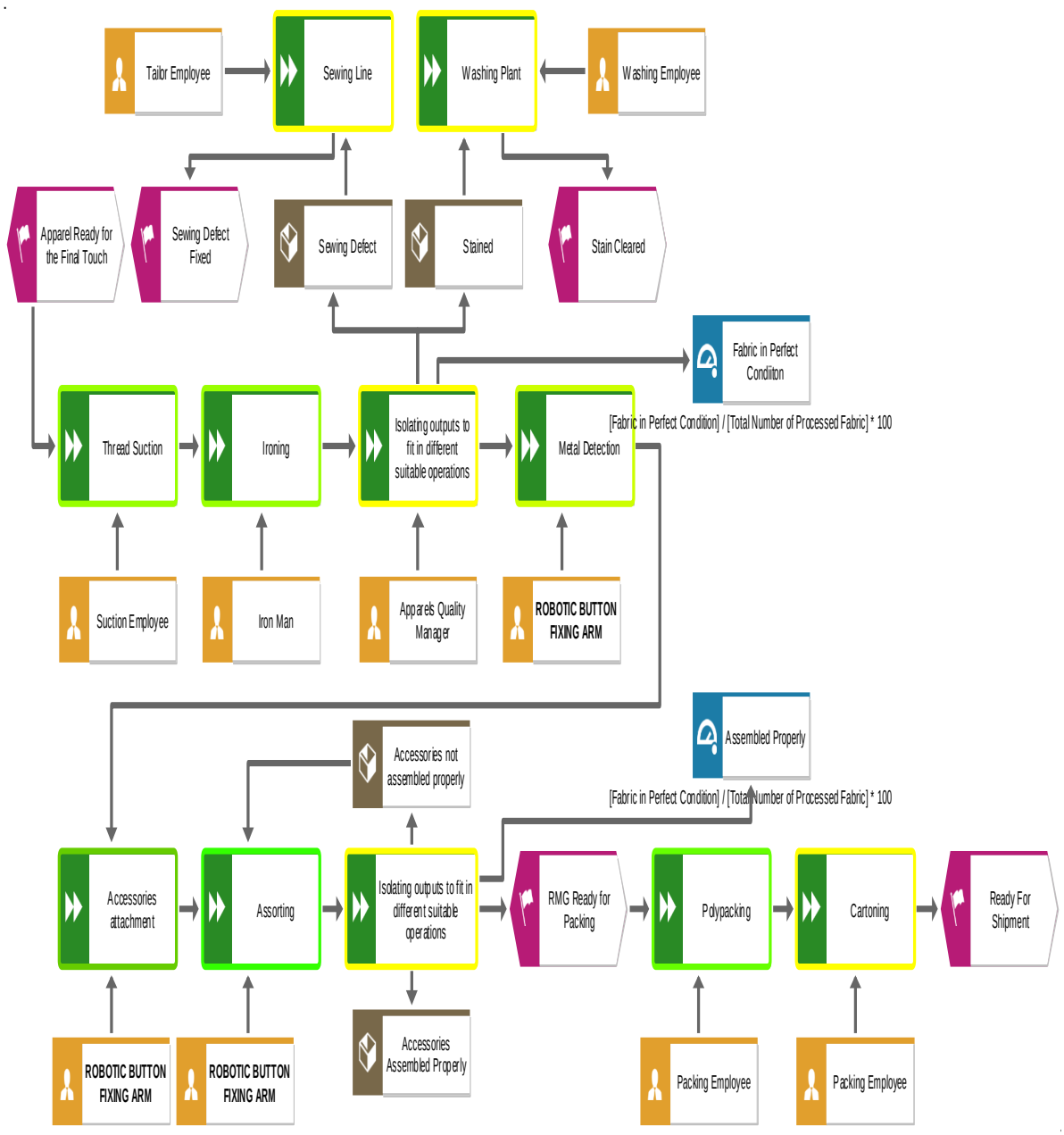

Figure 4. 30: EPC Diagram of Apparel Final Finishing by Human Employee (Source: Made by Author)

Simulation result when cartooning is handled by robots, Value added activities in Green border, Non-value added but must done activities in Yellow border, waste accumulator or related to store areas are in Red border,

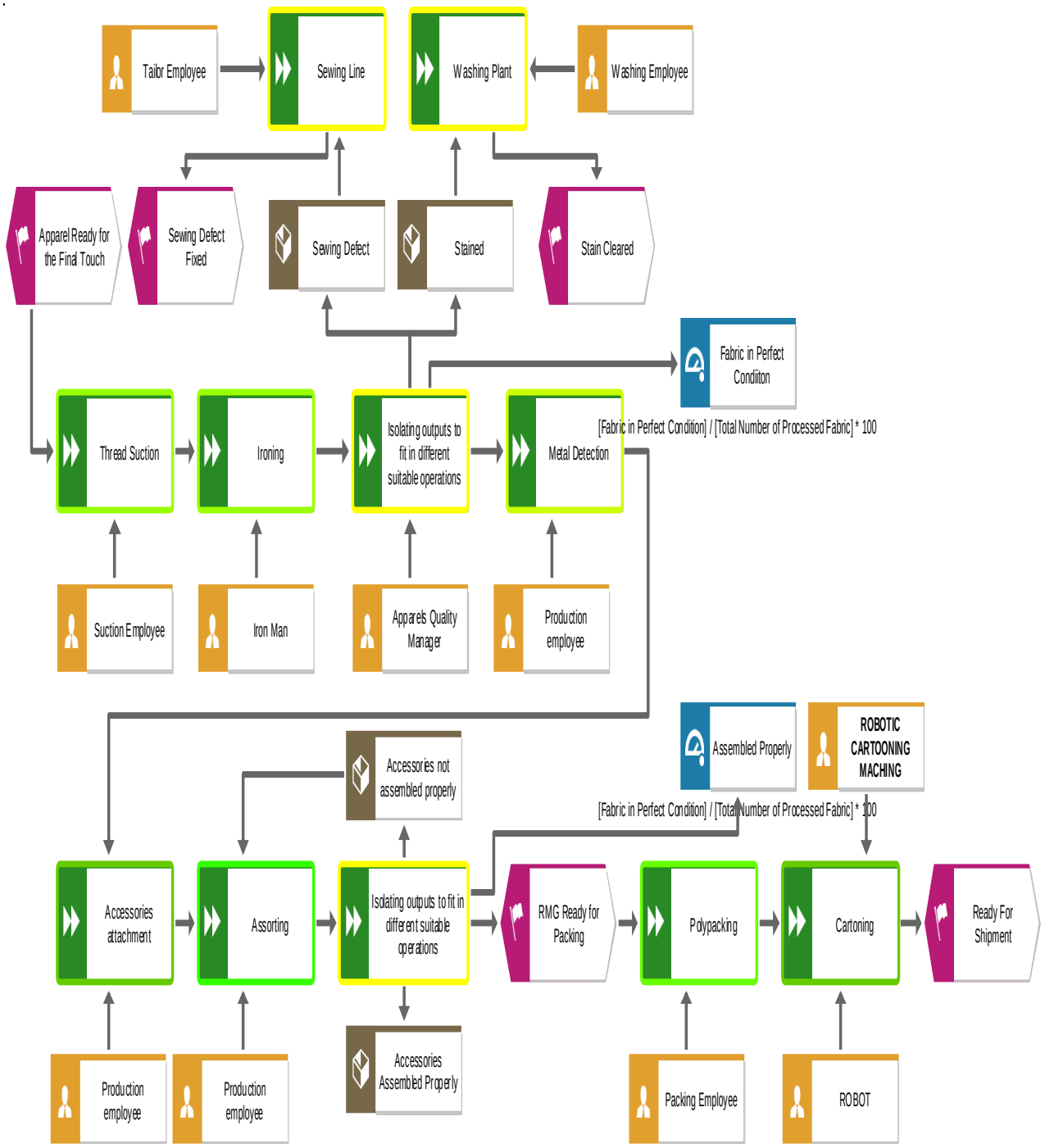

Figure 4. 31: EPC Diagram of Apparel Final Finishing Some Steps by Robots (Source: Made by Author)

4.10 EPC Diagram of Postproduction process and transport planning to send goods to final customer within accepted time

Transport planning and logistics management by human employee, Value added activities in Green border, Non-value added but must done activities in Yellow border, waste accumulator or related to store areas are in Red border

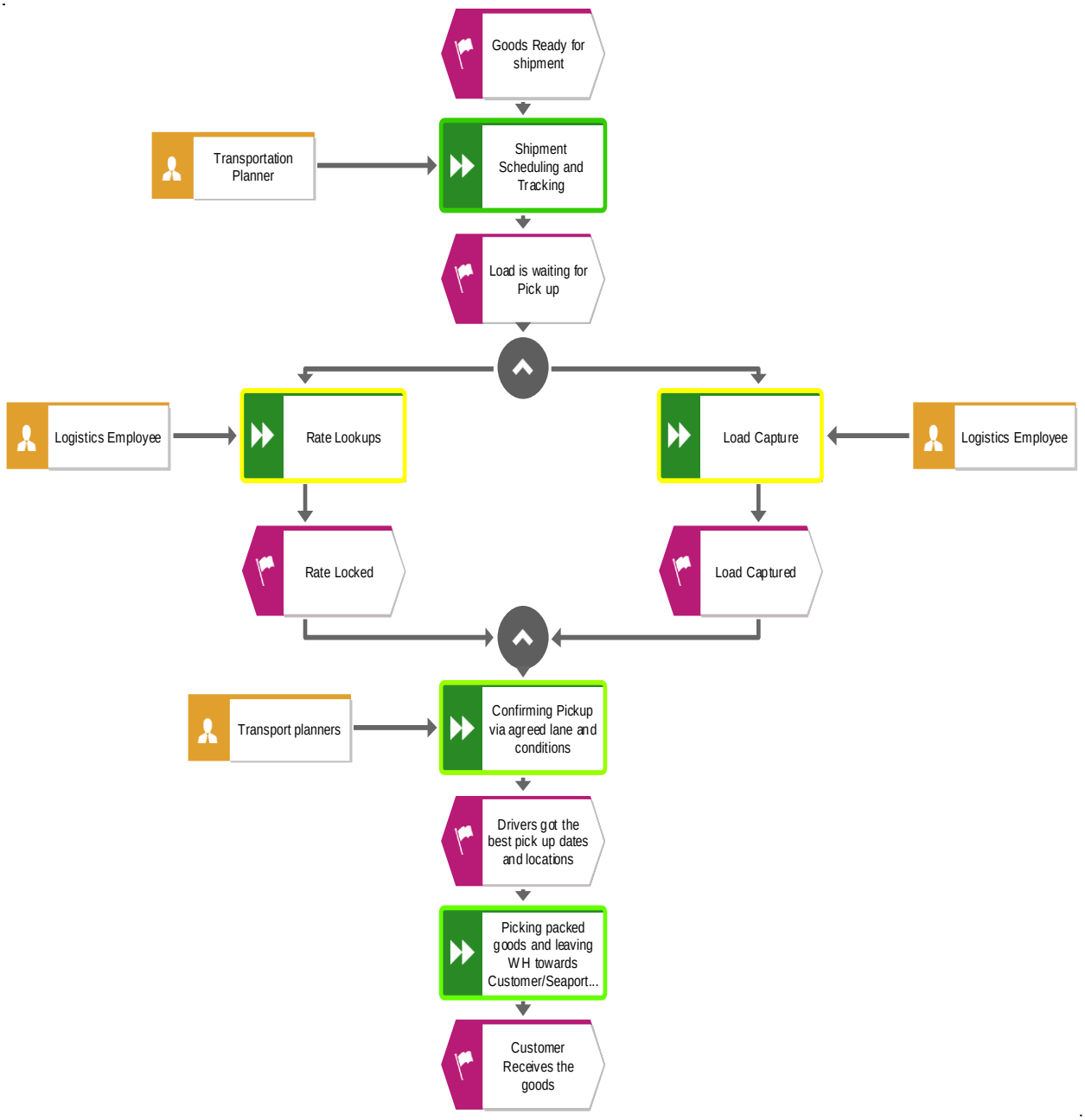

Figure 4. 32: EPC Diagram of Transport Planning by Human Employees (Source: Made by Author)

Raw Material Procurement *some steps replaced by RPA*, Value added activities in Green border, Non-value added but must done activities in Yellow border, waste accumulator or related to store areas are in Red border.

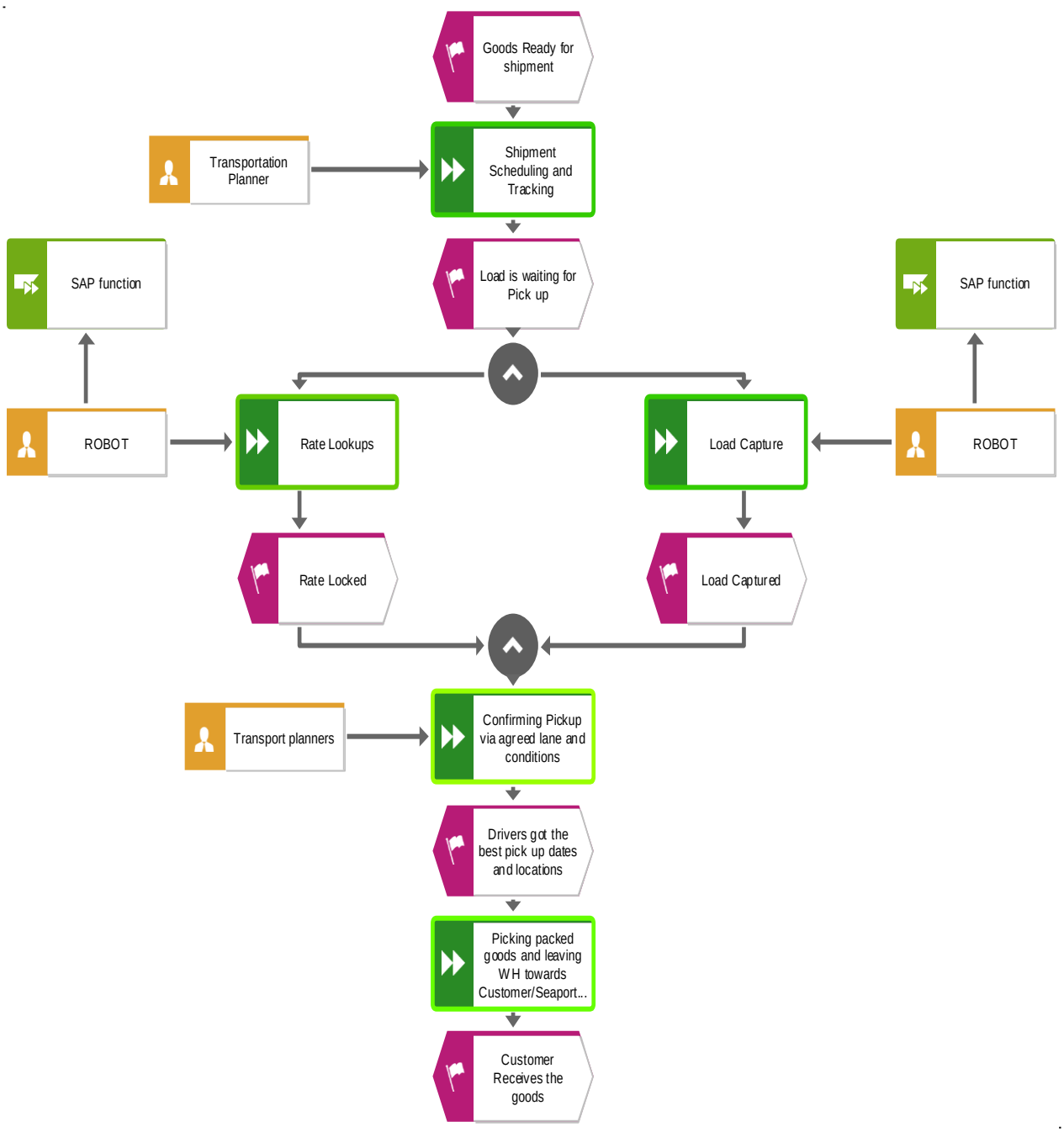

Figure 4. 33: EPC Diagram of Transport Planning Some Steps by Robots (Source: Made by Author)