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REVIEW

The Basic Layout of a Denim Textile Industry: A Basic Review

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ABSTRACT

Denim was produced in the city of Nîmes in France and was originally called the serge de Nîmes. The word denim is an English colloquialism of the French term: "denim." Day by day Bangladesh denim sector very much developed and helps to increase productivity. Bangladesh have seen a significant increase in investing in denim fabric manufacturing, increasing the country's production performance by reducing fabric dependence on imports. It is important due to its aspects of durability, and not easily torn which benefited physical laborers much. The government also plays a vital role in denim textile industry. This paper shows different section of denim textile industry such as: sewing section, cutting section, washing, IE and finishing department. The main aim of this paper is how to role all the section of denim textile industry. Textile education is insufficient without industry attachment, which bridges the gap between theoretical and practical aspects and acclimates students to the industrial world. We can gain about theoretical development on an industrial level from this attachment. We can understand more about the machines used in various departments, their technical specifications, characteristics, operating system, and so on, and we believe that without this type of industrial connection, it is impossible to obtain industry-based information about textile engineering adequately. The Industrial Attachment on Denim Manufacturing Technology was used to organize this study (sewing section, cutting, IE, washing section, CAD Section, and finishing department. Various operating procedures for the production of denim in the industry are presented in this paper. The technique and process of several procedures and processes are presented here such as machine specifications, manpower, maintenance, layout of the different section, dye processes and wet processes.

1. Introduction

By exporting these products, the textile and garment industry contributes significantly to Bangladesh's economic development. From 1972 to 2019, Bangladesh's gross domestic product (GDP) expanded from $6.29 billion to $286 billion, with $41 billion originating from exports, with a startling 84 percent coming from textile and garment exports [1]. Denim garments are one of the most important components of Bangladesh's textile industry. Denim garments are a fam-

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ily-friendly outfit that may be worn by people of all ages and have evolved into textile and apparel products [2]. Bangladesh is a textile industry-based country. Denim garments (trousers) are being produced with other garments to meet its demand in the competitive market of world and Bangladesh earned about 76% foreign currency from ready-made garments sector [3]. The Bangladesh denim industry is currently the top producer of denim in the European Union and United State markets. The denim industry is slated to go past 64 billion Dollar by 2020. By 2021, apparel manufacturers in Bangladesh will be exporting more than 7 billion Dollar worth of denim to traditional and non-traditional markets combined [4]. Two years back, Bangladesh was highly dependent on imported denim fabrics, but now Bangladesh can meet about 50% of the demand locally and are also exporting to some of the globally renowned buyers. In fine, Bangladesh has an enormous opportunity to grow in the RMG export markets as denim products have emerged as major players in the global markets. In this regard, Bangladesh government should prioritize denim products and provide all-out support to the entrepreneurs [5]. Denim garments are made from denim fabrics, which are one of the world's oldest fabric kinds and may always seem new thanks to years of intensive product development. There are a huge number of denim company remained in Bangladesh. One of them "Shasha Denims Limited" most significant in Bangladesh [6]. This company plays the most important role in denim sectors in Bangladesh. One of the most growing up Denim Garments in Bangladesh. The "Shasha Denims Limited" company has earned a reputation throughout the global woven industry as one of the foremost factories in Bangladesh for their commitment to quality, timely delivery and total value. This company is located at Savar, Dhaka-Bangladesh. The present chairman of this company is Mr. Anisul Islam Mahmud and managing director Mr. Shams Mahmud. The present address of this company is Plot: 184-193 & 277, DEPZ (Ext.) BD- Savar, Dhaka, Bangladesh. In 1991, this company was established, and the factory area is 25000 square fits. The most important factor of any factory is it's workpeople. Most of the development of a company depends on it's workpeople or labor or worker. We have investigated that more than 4,000 workers are working here. In this paper we discuss a principle layout of a denim industry of Bangladesh.

2. Methodology

In this review paper, all data and information are collected from secondary sources including previous articles, research papers and newspapers. Besides, mathematical calculations are collected from "Aaron Denim", a denim industry in Savar-Dhaka.

3. Different Departments

Departmental investigation was the focus of our investigation. Each and every company has it's own departmental section. Departmental section is also the most important things that categorized a company according to the company's rules and regulations. There are various departments in a denim industry which are discussed in the following sub-sections.

3.1 Store and Inventory

The stock of any item or resource utilized in a process is referred to as inventory [7]. Fabric inventory contains a variety of fabrics and accessories, such as sewing thread, needles, interlining, zippers, labels, and other items. Keeping a well-organized and well-equipped fabric inventory system is important for bulk productions in the clothing business. The following is a flow chart of the Fabric Inventory Management system in the denim textile Industry [8].

3.2 Sample Section

One of the most significant stages in the denim textile industry is sampling. Samples are a method to attract a buyer and confirming a purchase. Several types of samples are generated and submitted to the buyer for approval [9]. The ability of exporters to deal with every given style of garment is evaluated by samples. The buyer analyses the samples for style, construction, fit, or quality, among other criteria. Every factory has its own sampling department, whose duty it is to create various samples and obtain approvals for them. The sampling department produces samples based on the buyer's requirements and specifications. Spite of the fact of sampling is tough and time-consuming, it will help the exporter.

3.3 Cutting Section

Fabric cutting is the process of dividing out pattern parts of garment elements from a fabric lay as per pattern's specified specifications [11]. It's not like common cutting, where the actual dimensions aren't taken into account. The cutting process is the first step in the manufacturing of clothing. Fabric is cut into components (various shapes or patterns) in this procedure. Front, back, sleeve, and collar forms, for example). Multiple layers of fabrics are spread out on a table in mass production, and large amounts of fabric are used. At any given time, the certain quantity of garments are being cut. The term "lay" relates to the fabric stack that has been set out.

Several Actions in Cutting Section

There are different types of action needed in the cutting section. All are important in denim textile industry when

Table 1. Objective of different types of sample [10]

Serial no.	Type of sample	Objective
1	Proto Sample	To examine the garments design and style of the garment.
2	Fit sample	To ensuring that the garment fits properly.
3	Salesman sample	To show at numerous showrooms to obtain customers.
4	GPT sample	To see how far the clothing functions in various physical and chemical.
5	Size set sample	To assess the factory's ability to produce samples of different sizes.
6	Pre-production sample	To prepare a standard sample for mass production.
7	Pilot run Sample	To inform the buyer about the factory's realistic bulk industrial capacity.
8	Top sample	To convince the buyer that the same quality is maintained as in the sample.
9	Shipment Sample	To satisfy the purchaser that the quality of the product will be maintained to until termination of production.

we take this kind of action we increased our production [12]. All these actions shown in this paper:

Purchase fabric from the fabric store

The production manager provides the cutting department a cut order. The cutting in-charge develops a fabric requirement sheet or requisition slip for the fabric store to issue fabrics according on the cutting plan.

Relaxation of fabrics

Knitted fabrics require relaxation before cutting. After receiving the fabric from the fabric store, the cutting department opens the fabric from the fabric roll and lays it on the table for relaxation for some hours before cutting. Factories also relax fabric in the fabric store overnight after opening the fabric rolls.

Cut order planning

The cutting master plans the number of markers they need to prepare, the size combination to be set for each marker and the number of plies to be laid in each marker.

Cloth spreading/layering

Multiple layers of fabric are cut at the same time in mass production. As a conclusion, spreaders arrange the fabric on a cutting table in agreement with the total marker length. The layer height is restricted with one inch.

Planning marker

The cutting master plans marker ways, marker lengths and the numbers of plies to be laid in each lay.

Making marker

This is the process of sketching out garment patterns on the lay in preparation for cutting the garment components. The marker paper and placed on top of the layer after it has been laminated. Those companies without CAD markers make them by manually with paper patterns.

Fabric cutting

Following the formation of the marker, apparel patterns are cut and eliminated from the layer. Fabric layers are cut using a wide range of technologies, namely straight knife cutting, band knife machine cutting, and a computer-controlled automatic cutting machine.

Sorting, bundling, and numbering of garment plies (parts)

Layers are classified by size and colour after cutting the fabric. Stickers are being used to number each layer. Before being transferred to the next phase, bundles are stored on inventory tables.

Assessment of cut components

To maintain cutting quality, quality testers inspect standard cutting components at random. If any faulty components are identified, they are repaired. Its looks into the specifics of cut part inspection.

Sorting printed and embroidery panels

Printing and embroidery were done on cut panels as according to order requirements. After receiving printed and embroidered panels, size sorting is performed. The cutting section regularly double-checks printed and embellished panels.

Re-cutting panels

For garment components that need to be replaced in bundles, re-cutting is done. The sewing department gives out re-cutting requests for faulty garment parts. Block panels cut for the printing and embroidery operations are also re-cut. These panels are reshaped after receiving them from the printer or embroiderer.

Fusing garments component

Fusing in garment components is done to stiffen parts of a garment. If needed, fusing is done at the cutting section (e.g., fusing of the collar and cuff components of formal shirts).

3.4 Sewing Section

Sewing is considered as the heart of a garment in the fashion market [13]. After receiving all of the garment parts from the define phase, the parts are sewn together using a sewing machine. Sewing Section is a very important department in the denim textile industry because it allows the maker to obtain a complete aspect of the garments. This paper talks about the most important element of denim sewing section inspection.

3.4.1 Inspection of the Sewing Section

We need to identify a few basic needs that are vital in the denim sewing part for a smooth and perfect sewing operations [14]. In general, there are three phases to inspecting the manufacturing part of clothes. They are discussed in the following sub-sections.

3.4.2 Sewing Inspection

No needle holes should be seen. Only defective stitches, such as slipped stitches, staggered sewing, and asymmetrical stitches, should be visible. It's better to avoid puckering at the seams.

The density of the stitches should be comparable. Uneven stitch length should be minimized. A spot of oil or an uneven stitch length should be inspected.

3.4.3 Seaming Inspection

Unequal width of seam. Insecure seam. Miss matching of stripe and checks between two components along seam line. Trapping of foreign materials inside the seam. When the fabric's front and back sides aren't the same. Application of the improper stitch type or seam type.

Variation in shade between stitches.

3.4.4 Assembling Inspection

Any component that is the wrong size or shape. The clothing were the correct length. Any design in clothes is ignored. Any component in a garment that is not properly situated. Incorrect interlining placement and fusing. Variation in shade from one component to the next.

3.5 Denim Washing

In the denim sector, the garment was a new technique [15]. Normally, the term "washing" means the act of cleansing something. However, in the denim industry, simply cleaning clothing is not considered a garment wash. Denim washing is a technique for adjusting the appearance, comfort, and design of garments [16]. Solid coloured clothing and solid printed fabric are subjected to denim washing. Nowadays many types and objects of wash used in the denim textile industry.

3.5.1 Denim Washing Objectives

There are many washing objectives in denim textile industry. All are necessary for developed and increased the productions. All are included in this paper such as: To remove filth, dust, and waste from clothes, To remove size materials from garments, For garments wash shrinkage occurs, so accurate measurement can be found by customers, Fading effect is varied here by variation of an amount of detergent used, processing time and processing temperature, To increase the brightness of garments, To increase the smoothness of garments, To change the appearance of garments, To make directly wearable after purchase, To make garments become soft and handy and To remove harmful materials from garments [17].

3.5.2 Process Flow Chart of Denim Garments Washing

Denim is essential part of garments. Garments washing has some processes. All the processes are important for denim textile industry [18]. When washing is not good then we can't good products. Actual process flow chart for garments washing are mentioned in the following:

3.6 Administration

As companies increasingly sell services and look for opportunities beyond their home markets, their supply chains become more global [19]. Product design, for example, traditionally heavily global inputs, and products are sold around the world. Because of lower labour or material costs in other countries, some manufacturing operations or services may be outsourced. In this section, the current state of the textile industry in various nations has been demonstrated, including Pakistan, India, Vietnam, Taiwan, Thailand, China, and Bangladesh. It is important of our denim sector.

Management System of a Denim Industry

Each garment is run by a management committee. The managing director is responsible of that committee, and many executives in various positions assist him. The higher are listed below in order of power and function.

Table 2. Schematic flow chart of denim washing

Garments receive from the sewing department
↓
Garments sent to the dry process
↓
Hand scrapping
↓
Whickering
↓
Tacking
↓
Garments sent to the wet process
↓
Garments loading into the washing machine
↓
Extracting
↓
Drying
↓
Garments sent to the dry process
↓
P.Pspray
↓
P.P sprayed garments sent to the wet process
↓
P.P sprayed garments loading into the washing machine
↓
Washing
↓
Extracting
↓
Drying
↓
Garments sent to the dry process
↓
3D
↓
Curing
↓
Quality check (Q.C)
↓
Send to the finishing department

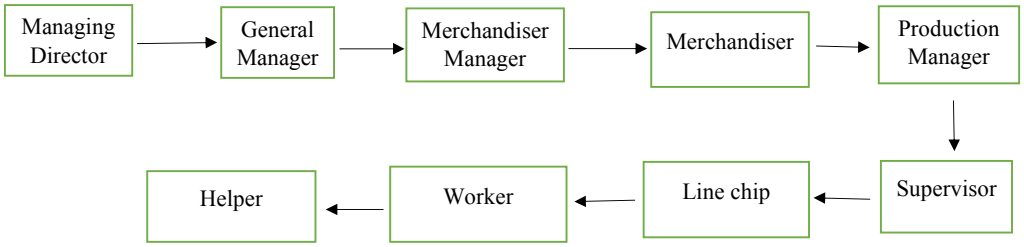


Figure 1. Management system of a denim industry

3.7 CAD Section

Because the denim textile industry is the most skilled labour-dependent industry, any cost savings through new Computer-Aided Design (CAD) technologies has become a requirement in gaining a competitive advantage, most universities have included CAD pattern making systems education and training as part of their clothing technology courses in recent years, in response to the actual needs of the fashion world for high-skilled fashion designers and clothing engineer [19]. CAD/CAM (Computer Aided Manufacture) systems enable a design to be created and altered fast without sacrificing creativity, and they improve communication and integration across product development systems. They've played a key role in reducing the cycle time, increasing accuracy, and placing clothes products in stores significantly closer to when customers need them.

With the increasing application of open-source software (OSS) in a various application, it's essential to determine whether existing OSS CAD software for garment prototype development can support the learning process. An objective assessment of CAD model complexity, per the summers and Shah can be useful in assessing case studies, evaluating the results of experiments, or evaluating student projects. The probable impacts of CAD model complexity have been recognized by a number of other publications. Modelling technique, according to Johnson, Valverde, and Thomison, comprises the amount of time spent on particular learning activities. In total, two licensed and two OSS systems were compared for their usefulness in producing ten different pattern designs for garments. The results of a day when evaluation of a collection of computer systems and licensed CAD systems are provided and critically evaluated.

Purposes of CAD in Denim Industry

Textile engineering (TE) and fashion technology (FT) educational and training are constantly subjected to official evaluation by various certification agencies. Traditional CAD and drawing courses mainly focus on geometric modeling, including wireframe, surface, and solid modeling. According to Ullah and Harib, the material of a CAD/CAM course should help students achieve at least the following four outcomes:

a. The ability to apply math, science, and engineering knowledge.

b. The ability to design a system, component, or process that meets the desired needs.

c. The ability to identify, formulate, and solve engineering problems; and

d. The ability to use the techniques, skills, and modern engineering tools required for engineering practice.

3.8 Industrial Engineering (IE)

Industrial Engineering is concerned with the design, development, and construction of system components of man, machine, and equipment, using specialized knowledge and skill in the technical, economics, and natural science, as well as the principles and methods of engineering analysis and design to specify, predict, and evaluate the result of such system [20]. It also plays important role in denim textile industry. Because using IE we developed our denim production. Without IE we can't get more products, day by day it has used more. It has some responsibility in denim textile: Capacity measurement, Work evaluation, Time analysis, operator performance, Verification, WIP (Work in Progress and Line balancing.

3.9 Finishing Department

Before to packaging garments into poly bags, finishing activities are carried out. A finishing department's primary duties include thread reduction, garment inspection, and ironing [21]. The wrapping division of the finishing department is where garments are wrapped, labelled, and stored. Without finishing department, we can't develop our denim sector. Finishing department is essential for denim sector. Without it we can't import products that's why we can't earn money that's why is important for denim sector of textile.

It has some function of finishing in denim textile industry. All these functions is very much important of industry. Without finishing we can't import the products that's why it is important of our denim textile section.

Thread Trimming

Thread paths and thread chain stores are not neatly trimmed in the stitching department. Helpers in the finishing department trim uncut threads and thread tails in garments. Defects in garments comprise uncut and loose threads.

Aesthetic and measurement inspections

At the finishing stage, all garments are graphically and quantitatively checked. Finishing checkers regularly check the whole garment from the inside out. Garment detailing, such as care labels and trimmings, are checked.

Button attach and Butting holing

In the finishing section, products to trimming such as buttons, grab buttons, and eyelets are attached.

Stain removal

Stains and spots can be detected on clothing. Prior to pressing, spots are eliminated with a hand spot gun or a stain remover system. Machine washing helps eliminate

dust and stains. As a result, the finishing department frequently washes items within the department.

Mending and repair work

Stitching and fabric defects in defective garments may require repair. Rather than sending damaged clothing to the stitching department, all repairs are completed in the finishing department.

Ironing clothing

Steam irons have been used to iron garments. This is done to get rid of creases in the fabric. Steam pressing are used to set parameters for knitted clothes. Garment pressing is done using vacuum pressing tables.

Folding and tagging

Pressed items are folded to a predetermined size. A Kimble gun or threads are used to attach tags such as price tags and hang tags on the clothing.

Packing the garments

Finally, the garments are folded properly and placed in poly bags according to the customer's specifications. After that, the individual poly bags are packaged into larger cartons.

Packing list creation

The shipping in-charge creates a packing list for the package. The finishing department notifies the concerned merchant whenever an order's packing is completed.

Internal shipment audits

Quality department performs internal shipment audit in the finishing department. Prior to the final inspection, this audit is conducted.

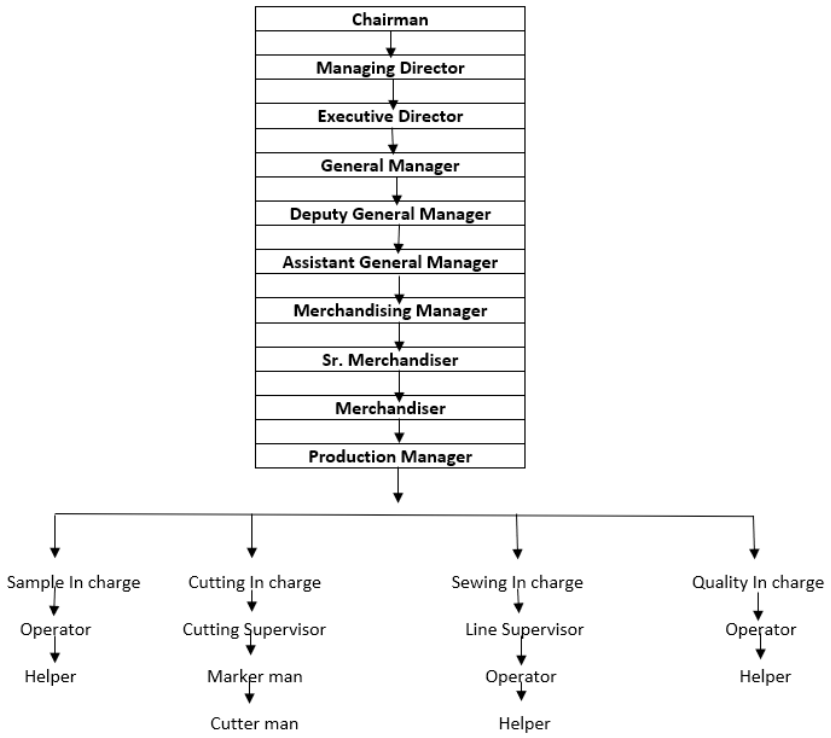
Reporting and documentation

The finishing department, like the other departments, keeps a list of manufacturing records for pressing and packing. All these functions are important of denim sector in textile finishing.

4. Manpower Organization

Manpower planning is one of the major activities which consumes a significant amount of time and effort of an IE at a denim textile manufacturing unit. Companies struggle to arrange and allocate desired machines and manpower to get the intended output, and many a times, unavailability of machine and manpower is taken as an excuse to hide or cover up the failures [22]. Though allocating the right people to the right work with the proper gear is a delicate problem, most this do not place enough emphasis on it. An imbalance among requirements (manpower or machinery) and actual allocation can create massive imbalances in the process, which can stymie the setup's performance. It is quite essential for denim sector of textile.

Table 3. Manpower organization in denim industry [23]



5. Raw Materials Used in Denim Industry

Different type of raw material used in denim textile industry such as fabric, button, zipper, sewing thread, label, different quality yarn, fibre**,** Dye stuff, Chemical and auxiliaries. In any production-oriented denim textile sector, raw material is an object. It is necessary for continuous productivity and increased fabric. Cotton, jute, wool, raw silk, and synthetic goods are being used as raw materials in the denim textile industry [24]. Textile raw materials are chosen based on the company's manufacturing policy, such as whether it is a composite mill or merely a spinning, weaving, or dyeing / finishing operation. All of these combine a good production of denim textile industry.

5.1 Fabric

Denim is a 100% cotton fabric that is woven in a twill weave with different colours of warp and weft yarn [25]. On the fabric surface of denim fabric, one color dominates. Denim is a common raw material used in the clothing industry. Denim fabrics are mostly made of cotton, while hemp denim is occasionally found. Denim fabrics are commonly used to make jeans, work clothing, and organic futon and pillow casings. Different types of denim fabric used such as Colored denim, Bubble gum denim, Denim from fox fiber, Crushed denim, Vintage denim, Ecru denim, Marble denim, Reverse denim [26].

5.2 Button

A button is a little round disc that is generally sewn onto an article of clothing or garment to close a gap or to enhance decorative feature. Buttoning is achieved by sliding the button through a stitched slit called a buttonhole or thread loop in the fabric. Buttons are fashionable because they decorate and improve the appearance of denim textile clothes. It is mostly used for increasing the appearance of garments [27]. Different types of button used in denim textile section as example: Plastic Button, Metal Button ,Wooden Button, Fabric Button, Shell Button Glass Button, Pearl Button, Ornamental button, Animal skin button, Ceramic button [28].

Sizes of Buttons

The button's size was calculated by its application. Shirt buttons are most often small and close together, but coat buttons are larger and split out [29]. Buttons are usually measured in lines (also known as lines and abbreviated L), with 40 lines surpassing 1 inch. For example, 16 lines (10.16 mm, standard buttons for men's shirts) and 32 lines (10.16 mm, standard buttons for female's shirts) are two most common button sizes (20.32 mm, typical button on suit jackets).

Table 4. Size of button

Ligne	Millimeters	Inches
14	8.9	0.37
16	10.1	0.41
18	11.4	0.38
20	12.7	0.51
21	13.3	0.53
22	14	0.57
23	14.6	0.59
24	15.2	0.63
27	17.1	0.67
28	17.8	0.69
30	19	0.75
32	20.3	0.83
34	21.6	0.86
36	22.9	0.88
40	25.4	1

5.3 Zipper

A zipper is an integral element of a garment that allows it to open and close. This is a type of trimming that can also be used as a garment accessory. In the apparel industry, the zipper is the most prevalent fastening device [30]. Zipper is essential raw material of denim textile sector. It consists of a slider with a tab, facilitating the opening or closing of two interlocking teeth or coil connected to a fabric tape strip. In making trousers, shirts and jackets, zip or zipper is an essential component used to open or close the garment's opening. Plastic zippers are not only more convenient for attaching garments, and they're also wind, dust, and waterproof, and they do not snag, stick, or rust. The innovation of plastic zippers also meant that they could be made in any color, allowing fashion designers another tool in their inventory. Many zipper used in denim textile industry such as Nylon coil zippers, Two way separating zippers, Closed-end zippers, Separating zippers, Continuous zipper chain, Metal teeth zippers, Molded plastic zippers, Pant zippers, Invisible zippers, Bag, zippers, Water repellant zippers, Lapped zippers.

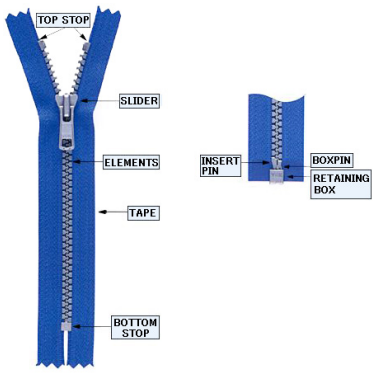


Figure 2. Main parts of a Zipper [33]

5.4 Sewing Thread

The apparel business employs a wide range of sewing threads. Sewing thread is a trim that secures the seams and ensures the functional features of a garment or other clothing product. The apparel business employs a wide range of sewing threads [31]. Swing thread is a necessary trimming that is widely used in the denim garment industry. Sewing thread is used to create clothing in the denim textile section. Threads are made by twisted two or more filament yarns together. Single filament is also used on occasion. Sewing threads can be made of natural, synthetic, or mixed fibers. When it comes to closing and top stitching seams, core spun threads are ideal since they produce high quality seams. Continuous bulk filament threads are ideal for overlocking or cover stitch seams. Natural and synthetic fiber blended core spun threads are ideal for sealing seams on high-quality denim garments. Continuous filament threads are ideal for creating optimal seam strength in leather items. Sewing threads are yarns that've been designed and created to pass quickly through a sewing machine. During the product's useful life, they form efficient stitches without breaking or getting distorted. A thread's primary objective is to provide aesthetics and performance in stitches and seams. Sewing thread is essential raw material of denim textile industry. There are different types of sewing thread used in denim textile section such as: Linen thread, Silk thread, soft cotton thread, Mercerized cotton thread, Glazed cotton thread, Viscose thread, Polyester thread, Nylon thread, Aramide thread, PTFE thread.

5.5 Label

Label is another raw material to use denim fabric. Label is a part of garments which indicates the various instructions about the garments [32]. Without any label a garment cannot be sold especially in export-oriented garments. The essential data like size of the garments, fiber type, care data, country of origin, company name, and trademark etc. It has some function: Product recognition, Suggestions for clothing sizes, promotes the product, customers' information Garments are categorized [33].

5.5.1 Types of Labels

There are mainly two types of labels used in denim textile industry such as

- Main label
- Sub label

5.5.2 Main Label

The main activities specifically the buyer's brand name or logo, such as C&A, Tom Tailor, Zara, and so on. From the customer point of view, the brand name indicates emotional contentment with the product. Customers prefer brand labels since they are the only ones who are aware about the brand and who consume it.

5.5.3 Sub Label

There are five types of sub label in denim textile section such as

I. Care Label
II. Size Label
III. Price Label
IV. Composition Label
V. flag Label

(I) Care label

Garments become dirty during end-use and it natural truth. These dirty garments are re-used by cleaning and ironing. For perfect caring of garments, some instructions are expressed by symbols which are called care code. The label in which, the care codes of a garment are placed called care label code. There are generally five types of instructions are used in a care label which are internationally recognized, called international care labeling code.

(II) Size label

Size labels vary from country to country. The different types of sizing for clothing include:

a. 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30
b. XXS, XS, S, M, L, XL, XXL
c. small, medium and large
d. 0, 1, 2, 3, 4, 5
e. One size fits all

(III) Price label

Show the price of garment in different currency depending on country.

Composition label

Content labels identify the type of fabric that has been used to make the garment, for example, 100% Polyester, Silk, 100% Cotton. It is very important that you choose the correct content label to attach to your garment. When buying fabric, you should always insist that the supplier confirms the fabric content in writing (or with swing tags). In some instances, the care and content labels are combined into one and this will cut down on the number of labels used on the garment.

(V) Flag Label

Sometimes garments contain small flag of buyer's country which is known as flag label.

6. Denim Washing

Denim washing is an attractive finish provided to denim fabric to increase its beauty and strength**.** Now-a-days denim washing is much popular both dry and wet washing process According to the fashion and appearance, there include new washing process and technology such as 3D or laser techniques [34]. In denim washing is done to produce effects like color fading with or without patchiness, crinkles, seam puckering, hairiness, Pilling softened-hand feel, stabilized dimension etc. Most of the denim wash effect vintage look.

6.1 Denim Dry Processes

Dry processes are important part of denim washing. Day by day dry processes is much popular in denim washing. Denim's dry process occurs before the wet process, and it alters the aesthetic look of the fabric through mechanical abrasion without influencing its construction or qualities. The garment takes on a good appearance after drying, and it also adds value to the product. The dry process is used to create fashionable clothes [35].

Table 5. Different types of dry processes in denim textile industry

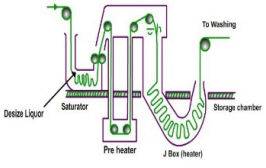
Dry process	Description	Image	References
Whiskering	**Materials and ways:** It requires abrasive paper or emery paper and some various ways such as by whiskering pattern, by Manual hand scrap, and by using laser Machine. **Functions:** It gives whiskered effect or fading effect on denim garments.		[36]
Hand Scraping	**Materials and ways:** After whiskering it requires abrasive paper, air dummy (horizontal), gum tape and Hand. **Functions:** This process removes the color or fade specific area of the denim garments.		[37]
Tagging	**Materials and ways:** Tag gun, tag pin, chalk and hand gloves are required for this process. **Functions:** It gives tagging effect at edge area of denim garments.		[38]
Grinding	**Materials and ways:** It requires Grinding machine and small size of stones are used in this process. This process is done manually. **Functions:** This gives old look appearance and creates high fashion denim garments.		[39]
Destroying	**Materials and ways:** It requires Grinding machine, grinding wheel, different size stones, niddle, knife, electricity, safety accessories. This process is done manually. **Functions:** It creates holes and worn-out white yarns which make garments unique and fashionable.		[40]

Dry process	Description	Image	References
PP Spray	**Materials and ways:** It requires water, Potassium permanganate (.4- 15 gm/L) (standard stock soln = .4 %) 3. Acetic acid (as per need). It also requires P. Spray Cabin, spray gun, air dummy, water circulation system, musk's, gloves, safety shoes and apron, electricity. **Functions:** It gives white or yellowish and bleach spot randomly in the denim garments.		[41]
Overall Crinkle	**Materials and ways:** It requires resin 20% and water 80%. It also requires washing machine, trolley, hydro extractor, curing machine, tie, rope, and thread **Functions:** It produces special effect on denim garments.		[42]
3D Crinkle	**Materials and ways:** This process is done manually or semi automatically using resins like low formaldehyde or DMDHEU (Dimethylol Dihydroxy Ethylene Urea) type resins Various supporting auxiliaries are used for this process. **Functions:** It gives 3Dimensional effect on denim garments at the thigh, hip and back knee area.		[43]
Laser	**Materials and ways:** It requires laser machine, leather hand gloves, goggles for safety and photoshop illustrator app. **Functions:** It creates whiskering or burning effect on the denim garments.		[44]

6.2 Denim Wet Processes

Following the dry process, wet processes including as desizing, enzyme washing bleach washing as well as other washes are applied to the raw garment to get the beautiful. The garment goes through multiple chemical processes in this procedure to eliminate contaminants from various production processes, give it a fresh look, soften it, and make it ready for the purchaser. In this paper shown the denim wet processes which is used in the denim textile industry. All the wet processes are important of our denim textile industry. Without wet processes impurities are included in the fabric so the products look unattractive, so it is important in denim textile sector.

Table 6. Different types of wet processes in denim textile industry

Wet process	Description	Image	References
De-sizing	**Chemicals & materials:** Detergents, Soda, Hydrogen peroxide, Anti back Stainer, stone. **Functions:** This process removes size materials, increase luster and absorbency.		[45]

Wet process	Description	Image	References
Normal/Regular wash	**Chemicals & materials:** Just water and slight detergent and back Stainer. **Functions:** This removes starch, dust and dirt from garments.		[46]
Stone washing	**Chemicals & materials**: Pumice stone, perborate and optical brightener if necessary and softener. **Functions:** This process gives vintage look, irregular color fading and softness of the garments.		[47]
Bleach washing	**Chemicals & materials**: Sodium hypo chloride, Hydrogen per oxide, and Sodium hypo-sulphite. **Functions:** It gives Light BLUE shade, removes the starch present on the garments, removes the size material from the garments and achieves soft effect on the garments.		[48]
Enzyme washing	**Chemicals & materials**: Neutral/Acid enzyme: G.B ZYME, Bio polish. **Functions:** This process removes floating fiber, smoothen surface of garments, gives high-low effect, increase luster and removes starch, sizing material.		[49]
Acid washing	**Chemicals & materials**: Stone, Potassium permanganate and Phosphoric acid. **Functions:** This gives Vintage/old look, Irregular fading and Softness.		[50]
Waterjet fading	**Chemicals & materials**: It does not need any chemical just need hydro jet and water. **Functions:** This increases the surface finish, texture, durability and other characteristics of denim garments.		[51]
Dip dyeing	**Chemicals & materials**: Pigments, direct dye, bleaching agents and dip dyeing machine. **Functions:** It creates special effects on denim garments.		[52]
Pigment washing	**Chemicals & materials**: Pigments, softener and water. **Functions:** It gives vintage look, softness, and fading effect.		[53]
Tinting	**Chemicals & materials**: It can be used different types of dyes like direct dye, reactive dye, sulfur dye and pigment colors. **Functions:** It gives new fashion designs and vintage or muddy look on the garments.		[54]

Wet process	Description	Image	References
Tie dyeing	**Chemicals & materials**: It can be used direct dye, pigments and bleaching agents for tie dyeing. **Function:** It makes different patterns and bleaching effect on the garments.		[55]

7. Mathematical Calculations in Different Sections

7.1 Warping & LCB (Long Chain Beamer)

Warping is the process of preparing yarn for weaving. It is the process of moving many yarns from a creel of single packages to a beam. The yarns will be placed onto the beam in a parallel sheet. The yarn arrangement in the dyed rope is transformed from a rope to a sheet shape in Long Chain Beamer. The rope pull from the can is moved upward to a guiding device in the Long Chain Beamer. The guiding device is probably positioned in the ceiling above the can. The following calculations are used in warping & LCB section.

1) $\text{yarn tension} = \frac{5905}{\text{count}} \times 0.075$

2) $\text{core length} = \frac{\text{Bag weight (gm)}}{\text{No. of core}} \times \text{count} \times 1.6933$

3) $\text{yards} = \text{meter} \times 1.09361$

4) $\text{operator production} = \frac{\text{warp length} \times \text{No. of ball warped}}{\text{Total no of ball}}$

5) $\text{Estimated yarn kg} = \frac{\text{warp length (mtr)} \times \text{Total Ends}}{1.6933 \times \text{count} \times 1000}$

6) $\text{Break \%} = \frac{\text{Total break} \times 1000000}{\text{Set length} \times \text{Total Ends}}$

7) $\text{Lbs}/\text{break} = \frac{\text{Total yarn kg} \times 2.2046}{\text{Total break}}$

8) $\text{Operator Efficiency} = \frac{\text{Total productionn (length mtr)}}{\text{RPM} \times \{\text{Total mun} - (\text{break} \times 2\}}$

7.2 Dyeing & Sizing

Dyeing is the process of incorporating yarn with color. It's done by soaking the yarn in a dyestuff-containing liquid. Indigo is the most frequent dye for denim. Because only the warp threads are dyed, the weft yarns are left natural undyed or bleached, denim is blue on the front and white on the back. On the other hand, sizing is used to improve the characteristics of surfaces. Sizing the warp yarn is necessary to avoid yarn breakage and, as a result, weaving machine production stops. The following calculations are used in dyeing & Sizing section.

1) Count

N = Count
L = The length of the sample
l = The length of the system
W =The weight of the sample
w = The unit of the weight of the system

Indirect system

$$N = \frac{L \times w}{l \times W}$$

Direct System

$$N = \frac{w \times l}{L}$$

2) $\text{Average count} = \frac{r1+r2+r3}{\frac{r1}{c1}+\frac{r2}{c2}+\frac{r3}{c3}}$; Here c1, c2, c3 are count with their ratio r1 : r2 : r3

3) $\text{weight ofyarn(gm/mtr)} = \frac{\text{Total Ends} \times 0.59}{\text{Average count}}$

$$\text{Or} = \frac{\text{Total Ends}}{\text{count} \times 1.6933}$$

4) $\text{Totalweightofyarn(kg)} = \frac{\text{Total length} \times \text{Total Ends} \times 0.0059}{\text{Average count}}$

5) $\text{Dossing} = \frac{\text{m}/\text{sspeed} \times \text{shade} \times \text{weightofyarn(gm/mtr)}}{\text{Feedsolution(g/L)}}$

6) $\text{Total Dossing} = \frac{\text{Total length} \times \text{Dossing}}{\text{M/c speed} \times 100}$

7) $\text{Box dye amount} = \frac{\text{shade\%} \times \text{Total volume}}{\text{M/c speed} \times 1000}$ or, $\frac{\text{g/L} \times \text{both volume}}{1000}$

8) $\text{Dye} = \frac{\text{shade\%} \times \text{pick up\%}}{\text{stock solution}}$

9) $\text{Volume of Black bath} = \frac{\text{Box g/L} \times \text{Total bath volume}}{\text{Feed g/L}}$

10) $\text{Pick up\% (sre chemical)} = \frac{\text{Total weight of sizing chemical}}{\text{Total weight of yarn}} \times 100\%$

11) $\text{RF\%} = \frac{\text{Total chemical} \times 100}{\text{volume of water} \times 1.8}$

12) $\text{viscosity} = \text{RF} \times 1.54$

7.3 Weaving

The process of weaving the warp and weft threads into the actual selvedge denim fabric takes place on a shuttle loom. The shuttle loom was popular in the past, although it has now been largely superseded by modern weaving machines. Selvedge denim, on the other hand, is still woven on shuttle looms to produce a genuine and high-quality fabric. The following calculation are used in weaving section.

1) $\text{Reed Space} = \frac{\text{Total Ends}}{\text{EPI}}$

2) $\text{EPI} = \frac{\text{Reed Count} \times \text{No. of yarn pass into reed eye}}{2}$

3) $\text{No. of warp in yarn selvedge} = \frac{\text{selvedge width in cm} \times \text{EPI}}{2.54} \div \text{selvedge width} = \text{for cotton}$

1.50 & for 1.70

$$4)\ \text{Loom Speed} = \frac{\text{motor PPM} \times \text{moto pully diameter}}{\text{loom pully diameter}}$$

$$5)\ \text{Loom efficiency percentage} = \frac{\text{Actually prod}}{\text{calculated prodn}} \times$$

$$6)\ \text{Moisture regain\%} = \frac{\text{yarn weight} - \text{Dried yarn weight}}{\text{Dried yarn weight}} \times 100$$

$$7)\ \text{Moisture content\%} = \frac{\text{yarn weight} - \text{Dried yarn weight}}{\text{yarn weight}} \times 100$$

8) Cloth cover factor,

$$\text{warp cover factor} = \frac{\text{EPI}}{\sqrt{\text{warp count}}}$$

$$\text{weft cover factor} = \frac{\text{PPI}}{\sqrt{\text{weft count}}}$$

Cloth cover factor = warp cover factor + weft cover factor - {(warp cover factor - weft cover factor) / 28}

7.4 Finishing

Fabric finishing is the final step in the denim manufacturing process. This is where the finished products are applied, and it can have a massive effect on how the cloth looks, feels, and fades. The following calculation are used as follows:

1) warp / length shrinkage (%) = (Greigh pick − Finished Pick) × 100 ÷ Finished Pick

2) Skew (%)

A → skew(C. M) ÷ 2.54 × 100 ÷ width (inch)

B → skew(inch) × 100 ÷ width (inch)

3) Meter to Yards

A → length(meter) × 1.0936 = yards

B → length(yards) ÷ 1.0936 = meter

4) After wash fabric shrinkage (warp/length)

= (Finished Pack − after wash pack) × 100 ÷ after wash pack

** All mathematical calculations are collected from "Aaron Denim" (Savar-Dhaka).

8. Conclusions

This paper showed the denim sector of textile industry and also we describe the different section of denim industry. Denim sector is important part of textile industry. The country benefited from denim sector because day by day denim sector developed. All the section played a vital role in textile industry. The main aim of the paper is knowing all the section of denim industry and also how to be increased productivity. When we read this paper we can easily know about denim sector of textile industry. Denim plays a vital role in textile sector. Sewing section, cutting section, IE department, washing sector, finishing department all are included in denim sector. Above this section we can't imagine denim sector of textile industry. In this paper we have shown sewing problems and how to overcome this problem, washing defects and how to minimize the washing problem, cutting measurement and function of cutting, industrial Engineering purposes and CAD system which They've played a key role in reducing the cycle time, increasing accuracy, and placing clothes products in stores significantly closer to when customers need them. Bangladesh is exporting denim products approximately 200 million pieces every year all over the world. Bangladesh is recognized as one of the most significant centers for denim apparel production in the world. It ranks as the second-largest denim garments exporter after China (According to WTO). The statistical review shows that the denim sector of Bangladesh plays a very important role in the denim market all over the world. Especially after the denim sector of China, Bangladesh's position. Seeing such a huge achievement in the denim sector of Bangladesh, other countries can also become competitive. Denim garments are one of the most necessary parts of the textile sector in Bangladesh. In the global market all over the world, Bangladesh is now more prominent as a supplier of denim products. Therefore, Bangladesh will be more interested to take the denim sector to the first position. By reviewing this paper, the manufacturer of denim garments in Bangladesh and other countries will be more interest and improve their economy by exporting their denim products all over the world. Finally, it will help to develop the economy and people living standards of Bangladesh.

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ARTICLE

Companies and Sustainable Development: The Adequacy of Environmental Impact Assessment for the Management of Environmental Risks

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ABSTRACT

The choice of the environmental risk management instrument to be used within the scope of corporate governance in companies is of paramount importance to avoid or mitigate the triple environmental responsibility to which they are exposed. In this sense, the following research problem arises: The Environmental Impact Assessment (EIA), an instrument of the National Environment Policy and a model of environmental risk management adopted by some companies, proves to be efficient, effective and effective for the fulfillment of the duty to protect the environmental balance and, therefore, for sustainable development? The present study aims to elucidate this research problem. To this end, analyzes were carried out on risk and environmental damage, from a perspective of the socio-environmental function of companies today; the need for a new posture by companies in view of the reflexes of environmental risks in business activity; and the question of the adequacy or inadequacy of the EIA as an instrument of the National Environment Policy and as a model for managing environmental risks and damages, in the pursuit of sustainable development. The method of approach used was the deductive one, and the research was carried out using the method of bibliographic procedure, through which research was carried out on books, scientific articles and legislation. The result points out the inefficiency and ineffectiveness of the EIA for the management of environmental risks and, thus, for the fulfillment of the duty to protect the environmental balance by companies.

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1. Introduction

In Brazil, with the promulgation of the 1988 Federal Constitution, the protection of the environmental balance reached the status of constitutional duty of the Public Power and of the community, with the purpose of guaranteeing the fundamental right of present and future generations to live a quality life in an ecologically balanced environment, as provided for in Article 225, *caput*, of the 1988 Federal Constitution. Faced with the duty to protect the environmental balance, companies came to be understood as an instrument for the achievement of that constitutional purpose.

In order to comply with the constitutional duty to protect the environmental balance, companies must use environmental risk management instruments to avoid or at least mitigate environmental risks arising from their production processes, also aiming to avoid other types of risks inherent to the practice of economic activity, such as right risks and reputational risks.

Thus, the choice of the environmental risk management instrument to be used within the scope of corporate governance in companies, is of paramount importance to avoid or mitigate the triple environmental responsibility to which they are exposed. This is where the problem arises, in Brazil as Law No. 6,938/81 - Law on National Environmental Policy - provides for Environmental Impact Assessment (EIA) as one of its instruments, encouraging companies to use it as an instrument for managing environmental risks. But does the EIA give efficiency, effectiveness and effectiveness to the environmental risk management process of companies, in order to guarantee the fulfillment of the duty to protect the environmental balance and, as a consequence, guarantee sustainable development?

This is the research problem that we aim to clarify with the present study, which, once completed, can provide managers with subsidies about the choice and use of EIA as an instrument of environmental risk management in companies.

This research problem is justified, as countries such as Canada, the Czech Republic, Denmark, Hong Kong, the Netherlands, New Zealand, Portugal, Slovenia, South Africa, Sweden, the United Kingdom and the United States have already adopted, to a lesser or greater extent, the Strategic Environmental Assessment (SEA) for environmental management in their territories, thus considering the potential impacts, including cumulative and synergistic impacts; carrying out a better consideration of the alternatives; increasing accountability and efficiency in strategic decision-making; and involving stakeholders for more transparency and better governance.

Thus, the justification for conducting the research is the fact that, if the EIA proves to be inefficient and ineffective for the management of environmental risks, the companies that may be using it as an instrument of environmental risk management will be too exposed to the triple responsibility environmental impact, which may impact your financial and image health.

Adopting the deductive approach method, having as a parameter the Brazilian case of environmental management based on the EIA method, we sought to carry out, through a bibliographic procedure, a bibliographic review in order to seek answers to the research problem.

Thus, initially an analysis was carried out on environmental risks and damages, under the socio-environmental function of companies today. Then, investigate the need for a new attitude of companies in the face of the consequences of environmental risks in business activity. Subsequently, the question of policy and damage of the search or the adequacy of the instrument of the national environment of risk management and environmental damage.

To obtain the results desired by the research, the method of approach followed, as said, was the deductive, and the method of procedure was the bibliographic, legislative and jurisprudential research, having as a background a reference system based on Law and Economics, whose exponent is Richard Allen Posner.

In conclusion, it is expected that companies can better delimit the environmental risks of their production processes and, with this, can reduce the occurrence of environmental damages or, at least, mitigate the effects resulting from them, reducing, as a consequence, the risk of their liability environment, through the election and adoption of an environmental management process that allows, from the beginning of the decision-making process, the adequate treatment of environmental issues involved in its most varied production processes.

2. Literature Review

2.1 Environmental Risk and Damage: An Analysis from the Perspective of the Socio-environmental Function of Companies Today

The notion of risk is linked to the probability of occurrence of an event or hazardous exposure, which may have a harmful result [1]. For Frade, "the concept of risk privileged by risk theories refers to the probability of the occurrence of harmful, adverse effects" [2]. Therefore, the risk can be understood as the probability of the occurrence of a dangerous event or exposure, which can generate a

harmful result.

Risks that cannot be easily related to or attributed to human actions are called natural risks. Among the natural risks, the following types of risks can be mentioned: climatic risks, arising from the climate; tectonic and magmatic risks related to earthquakes, tidal waves, tsunamis and volcanic eruptions; geomorphological risks, related to erosion processes, such as the formation of gullies and gullies, mass movements, such as landslides and landslides, as well as wind erosion and the thawing of high snow; and hydrological risks related to floods [3].

Technological risk is that related to the *lato sensu*, productive process that covers all factors of production, work and condition of human existence. Thus, the greater the human consumption, the greater the production, which will result in an increase in hours worked, increasing the employment of equipment and people, as well as the demand for environmental resources (raw material) to obtain finished products, leading to the appearance technological risk, typical of the Risk Society [4].

Environmental risk can be understood as one that encompasses other risks, since all risk situations are linked to what happens around them, that is, they are linked to the environment in a broad sense, be it natural, artificial, labor or cultural. Thus, environmental risk can be understood as a combination of the probability of the occurrence of a dangerous event or exposure with the severity of the environmental damage that can be caused by such a dangerous event or exposure. It is important to note that risk is a social object, as there is no risk without someone who perceives it and is exposed to its effects. In this sense, Veyret states that "[...] risk is the translation of a threat, of a danger for those who are subject to it and perceive it as such" [5] (my own translation).

On the other hand, damage is understood as the loss suffered by the victim, which is characterized by a decrease in the victim's legal or patrimonial asset, against his will, as a result of a certain harmful event. Therefore, the damage can be understood as a negative change in the legal, material or moral situation, caused to someone by a third party who is obliged to be compensated [6].

Risk and damage are indispensable assumptions for the configuration of liability in the environmental criminal and administrative scope, however, for the configuration of liability in the environmental civil scope (obligation to repair the damage), only the damage appears as an assumptions for the configuration of liability in the environmental criminal and administrative scope, however, for the configuration of liability in the environmental civil scope (obligation to repair the damage), only the damage appears as an assumption, because without proof of damage, no one can be held civilly liable [7]. Thus, for the configuration of environmental civil liability, the occurrence of damage to the environment is indispensable, whereas for the configuration of environmental criminal and administrative liability, in most cases, the existence of a risk of damage is sufficient.

The legal definition of the environment is contained in article 3, item I, of Law No. 6,938/1981, which defines it as being the "[...] set of conditions, laws, influences and interactions of a physical, chemical and biological nature, which allows, shelters and governs life in all its forms " (my own translation). Article 3, item II, of Law No. 6,938/1981, defines environmental degradation as being "[...] the adverse change in the characteristics of the environment" (Brazil, 1981, my own translation). In turn, Article 3, item III, of Law No. 6,938/1981, defines pollution as being:

> *[...] the degradation of environmental quality resulting from activities that directly or indirectly:*
>
> *a) harm the health, safety and well-being of the population;*
>
> *b) create adverse conditions for social and economic activities;*
>
> *c) adversely affect the biota;*
>
> *d) affect the aesthetic or sanitary conditions of the environment;*
>
> *e) launch materials or energy that do not comply with the established environmental standards; [...]* [8] *(my own translation)*

The aforementioned legal provisions indicate that the environmental damage is a direct result of the adverse alteration of the environment, caused by natural phenomena or by human actions, which directly affects man in his health, safety and well-being; creates adverse conditions to social and economic activities; and it adversely affects the biota and the aesthetic and sanitary conditions of the environment.

Fiorillo defends the concept of damage as being an injury to a legal asset, even though this injury is not the result of an illegal act [9]. Thus, if there is an injury to an environmental asset, a legal asset of a diffuse nature [10], it would be an environmental damage. For Milaré "[...] environmental damage is the damage to environmental resources, with consequent (sic) degradation-adverse change or in pejus - of ecological balance and quality of life" [11]. Therefore, environmental damage can be understood as any injury or negative change in the environment that occurs due to a natural event or a lawful or illicit anthropic action, which directly affects human beings in their health, safety, social and economic

activities.

Environmental damage has characteristics that denote the seriousness of its occurrence to society, such as the pulverization of victims, due to its cross-border effects; the difficulty of repair; and the difficulty of valuation. Transboundary effects can be understood as the effects resulting from environmental damage occurring in the jurisdictional area of a State, which move to the jurisdictional area of another State, whether or not passing through an area of international jurisdiction, provided that the effects of environmental damage occurred will affect at least two states. The Basel Convention on the control of transboundary movements of hazardous waste and its deposit, ratified by the Brazilian Government through Decree No. 875, of July 19, 1993, provides in its Art. 2, number 3, that: "Transboundary Movement" means any movement of hazardous wastes or other wastes from an area under the national jurisdiction of a State to or through an area under the national jurisdiction of another State or to or through an area not covered by national jurisdiction of any state, as long as the movement affects at least two states [...]" [12].

Regarding the spraying of victims, it must be considered that, due to the diffuse nature of the environmental good, any damage caused to it will necessarily result in a diffuse collective of victims. Environmental damage is considered difficult to repair due to the fact that human beings, in most cases, are unable to restore the environment to the situation as nature created it. Due to the difficulty of repairing the environmental damage, it is not always possible to calculate the value for its repair, hence its characteristic of difficult valuation.

Thus, environmental damage can be conceptualized as any injury or negative change in the environment, which occurs due to lawful or illicit anthropic action, or even a natural event, which directly affects human beings in their health, safety, social activities and economic and for which he is responsible, directly or indirectly, natural or legal person, public or private, who is obliged to repair in its broadest possible sense.

The Western economy model, highly guided by the predatory exploitation of environmental resources, was aggravated by industrial development, which subjugated nature, making it a prerequisite for consumption and the market, of the way of life in the industrial system. Over time, humanity has learned, through the accumulation of knowledge, to defend itself against threats from external nature. However, it is practically defenseless against threats of an internal nature, which, absorbed by the industrial system, generates dangers in proportion to daily consumption.

Thus, they represent the "bankruptcy of modernity, emerging from a postmodern period, as the threats produced throughout industrial society begin to take shape" [13].

In today's society, in the face of patent environmental risks, the logic of risk production dominates the logic of wealth production in industrial society, having, as a theoretical and practical basis, the threats to life, provided by risks, considerably enhanced by the modernization of production, which do not respect borders, revealing themselves as global threats. Then, the paradigm of today's society emerges, based on the following question: How to avoid, isolate, control, minimize and socialize threats and risks co-produced today, without compromising the modernization process and without breaking the boundaries of the socially just, the environmentally balanced, the economically viable and the politically correct?

To answer such a question, prefacially, it is necessary to differentiate personal or individual risk from global risk. The first has the possibility of reaching a single person, due to its boldness or spirit of adventure, the second translates into the possibility of impacting the existence of life on Earth, and may even extinguish it.

Environmental risk is embodied in global risk due to its cross-border characteristic, in which an environmental damage that occurs in one place on the planet ends up impacting a society located in another place, sometimes thousands of kilometers away.

The expansion of environmental risks in today's society, due to its neglect or mismanagement, leads to the emergence of new challenges for democracy. Environmental risks represent not only risks to the environment, but also to a society's economy, culture and politics. Therefore, such risks come to occupy a prominent place in social, environmental, political and economic issues worldwide, with regard to the distribution of environmental risks, together with the internalization of wealth by companies, both arising from highly industrialized and globalized production processes.

The risks indicate something to be avoided, so, in view of the socialization of environmental risks, companies and scientific and professional groups should be Concerned with managing the positive and negative externalities of their productive activities, they are targets of public criticism, which can lead them, if they do not manage their externalities, to reduce sales and market losses.

2.2 Environmental Risk and Its Reflections in Business Activity: The Need for a New Posture

As seen, environmental risk presents itself with

the simple idea of the possibility of the future event of an event harmful to the environment, through the development of a given activity. Risk management is an important way for companies to avoid problems arising from environmental risks, especially direct risks and reputational risks. Direct risks are linked to environmental problems generated by the production processes developed by the companies and can have serious impacts on their debt settlement capacity, in view of their potential to generate environmental liability, with certainty of responsibility for repairing environmental damage caused by part of companies [14]. Reputation risks are related to negative public opinion about companies that do not comply with technical and legal rules, generating environmental damage. These risks have an impact on the reputation of companies in relation to society, and may damage their image, which is part of their assets and important for the full development of their activities [15].

Companies are increasingly exposed to reputational risks in their daily lives. An example of this is the reputation risks arising from the occurrence of environmental damage. The corporate name and reputation, built over decades, may collapse due to the lack of capacity of executives, directors or even operational staff to react adequately in the face of environmental damage resulting from the business production process. The lack of capacity to react, in most cases, is linked to the absence of policies, plans and programs capable of preventing environmental damage or, when it occurs, controlling and reversing its harmful effects.

Environmental risks are closely related to financial risks, since the occurrence of environmental damage can reduce the productive capacity of an economic activity or even interrupt it, a fact that can reflect on the financial health of companies, leading them to default on their commitments, either in the settlement of debts, or in compliance with the measures to mitigate environmental damage assumed at the time of environmental licensing. In the first case, financial risk is present in the possibility of reclassification of credits to the list of bank assets with lesser appreciation, in view of the difficulties in receiving them. In the second case, the financial risk is present in the legal possibility of companies having to bear the compliance with the measures to mitigate environmental damage, due to the objective, integral and solidary environmental civil liability. In addition, there is also a negative repercussion of the image of companies with society, reflecting financial risk to the extent that it may result in a reduction in the number of customers or, at least, in greater difficulty in attracting new customers.

Regardless of the possibility of eventually being held responsible for environmental damage caused by one of their production processes, companies must align themselves with contractual and environmental principles in the formulation of their institutional arrangement, due to the obligation to keep objective good faith [16] in all the phases of its production and distribution processes, including the pre and post-production and distribution processes.

In this context, direct risk and reputation risk can be minimized through sustainable practices to be developed in a transversal and multidisciplinary way, as per the environmental principles of ubiquity and cooperation [17], covering all sectors and activities of companies, which must cooperate with each other so that, in addition to guaranteeing a sustainable performance of its internal public, they also guarantee a sustainable performance of the external public, mainly of its customers, through the internalization of environmental risks to the costs of its production processes, as recommended by the principles of polluter pays, prevention and precaution.

The risk to the existence of life on the planet is so serious that it requires thinking and acting across the many professional areas [18]. Scientific knowledge, incapable of meeting the existing demands in the risk society, must give way to other qualities of information and knowledge capable of guiding the decision-making processes with regard to doing or not doing, in the face of incomprehensible or unknown risks [19].

The environmental issue can no longer be the object of analysis only in the natural sciences, but, due to the multiplicity of aspects that involve it, it must be treated in a transversal way, being analyzed from different perspectives, by different professionals, such as, for example, biologists, chemists, urban planners, doctors, sociologists, administrators, engineers from the most diverse branches, psychologists, agronomists, educators, economists and lawyers, among others.

Environmental risks have generated a market demand that departs from the liberal model of development, characterized by the internalization of profits and the socialization of negative externalities, among them environmental risks, and is closer to the development model, characterized by the internalization of profits and negative externalities, under the guidance of the polluter pays environmental principles, prevention and precaution, previously discussed.

In this regard, the market no longer admits purely polluting companies, which do not fit into a sustainable development model, because of this, the incorporation of the environmental variable in the decision-making process of companies is a measure imposed by the market. In this

sense, managers and economists have allied themselves with professionals from the most diverse areas, in the search for a management model that promotes not only economic growth, detached from issues of social, cultural and environmental development, but also economic development that, oriented by economic, social and environmental principles orienting the internalization, by companies, of profits and negative externalities, including environmental risks, in the search for the longed for sustainable development [20].

The choice of the environmental risk management instrument is of paramount importance for the prevention and mitigation of environmental risks and damages and, as a consequence, for the mitigation of the triple environ mental responsibility of companies. It is the structuring of institutional arrangements - governance mode - that allow the positive study of company strategies, reflected in the elaboration of institutional policies, plans and programs, which characterize them as an intelligent nexus of contractual and non-contractual relations.

In this context, with the Environmental Impact Assessment being the model of environmental risk management chosen by Brazil, as it appears in Art. 9, item III, of Law No. 6,938/1981, as an instrument of the National Environmental Policy Environment, the verification of its efficiency, efficacy and effectiveness is of great importance for the achievement of the desired sustainable development.

2.3 The [in] Adequacy of the Environmental Impact Assessment as an Instrument of the National Environmental Policy and as an Environmental Risk and Damage Management Model

According to the principle of environmental impact assessment, activities that present risks of negative impacts on the environment and, therefore, in view of the principles of prevention and precaution, must be submitted to the competent environmental licensing, must be subject to Environmental Impact Assessment - EIA, in order to provide information capable of forming the conviction of the environmental authority responsible for issuing the license or authorization. The Rio de Janeiro Declaration, one of the documents resulting from the United Nations Conference on Environment and Development, Eco-92, brings the EIA as its number 17 principle [21].

The EIA must contemplate the identification of the potential environmental problems that can be expected, the potential benefits and losses of the project and the incorporation of appropriate mitigation measures, which even include the adequate monitoring of the problems considered as critical, in order to avoid the appearance of new ones degraded areas. The EIA has steps to be observed, and each step is intended to obtain one or more environmental licenses provided for in Art. 19, of Decree No. 99,274/90, which are the Prior License (LP), the Installation License (LI) and the Operation License (LO). During the environmental licensing phase of projects, the entrepreneur must inform the competent environmental agency about the characteristics of the enterprise that he intends to install and operate, indicating the type of activity, location, size, among other data and information that allow the environmental licensing body determine the type of environmental study to be required.

It appears that the EIA is carried out within the scope of the projects, that is, the EIA is used to verify the environmental risks contained in projects whose implementation decision had already been taken at an earlier stage, which is the planning phase, with the purpose of shaping projects to meet the legal parameters for obtaining environmental licenses and/or authorizations necessary for the installation and operation of economic enterprises. The EIA, as an instrument of environmental risk management, is restricted, exclusively, to the control of the direct impacts of projects on the environment. Thus, EIA is an instrument used in the project phase and not in the planning phase, when institutional policies, plans and programs are formulated, as well as the projects that will be executed by the company are chosen.

Thus, the EIA does not act as an instrument for the formulation or modification of policies, plans and programs aimed at mitigating environmental risks and damages, or even for the election of projects that will be carried out by companies. Such an instrument is limited to assessing the environmental risks linked to production process projects whose implementation has already been decided, that is, EIA is used to legitimize the environmental viability of projects whose implementations have already been decided at an earlier stage, whatever the stage of planning.

At EIA, the environmental feasibility assessment does not take place in the planning phase, in which the conception, election and preparation of projects occur, but in the implementation phase, that is, when the project already exists and its implementation has already been decided by the entrepreneurs, demonstrating the inability to integrate EIA into project planning, identified by Leonard Ortolano and Anne Shepherd as an "integration problem". Because it is carried out at the end of the decision cycle, in the project implementation phase, the EIA ends up being motivated by non-scientific factors. In this sense, Ortolano and Shepherd state that:

Decisions on significant public or private devel-

opment projects are not, in fact, made following the logic of the rational model. Instead, decisions are influenced by 'nonscientific' factors, such as agency and corporate power, and interest group politics [22].

In this model, entrepreneurs, proponents of projects, do not give the same weight to environmental and economic objectives, as they consider irrational the use of resources to carry out EIA to inform the planning of a certain project when they do not even know about the probability of its success.

In Brazil, the EIA, carried out through the Environmental Impact Study, reveals itself as the fundamental regulatory instrument at all levels of government, an instrument that has become an administrative bureaucratic process, without adequate consideration of factors such as location, possible technological alternatives, environmental impact and potential mitigation measures [23].

In the EIA, the steps to follow up and monitor the implementation of the projects do not occur, nor does the proper assessment of the effectiveness of the mitigation measures for negative impacts occur, which prevents the adequate and timely identification of adverse effects that have not been predicted by the environmental licensing process and, with that, it allows the continuity of projects that are causing damage to the environment without the appropriate mitigating consideration.

The EIA, as an instrument of environmental risk management, since it is not subordinated to an institutional arrangement aimed at mitigating these risks, is limited to the specific verification of the environmental risks involved in a given project, ignoring the geographical context contained, for example, in regional development plans, river basin management plans, Economic-Ecological Zoning, Environmental Audits, environmental monitoring, among others.

This statement can be exemplified by the process of degradation of the Tietê River by industrial pollution and domestic sewage in the Greater São Paulo section. Between the 1940s and the 1980s, the political permissiveness revealed in environmental licensing that did not consider the cumulative and synergistic effects of the most varied economic enterprises installed along the Tietê River, resulted in the disorderly expansion of the São Paulo industrial park, which, without due environmental counterparts, resulted in the rapid infeasibility of using the waters of the aforementioned river to supply the city, due to having reached intolerable levels of pollution, noticed through the simple olfactory perception of those who enter the municipality of São Paulo by the River Marginal Tietê.

The human being, as a rational being, seeks to maximize his gain (well-being). To this end, it seeks to expand its source of obtaining wealth and, with that, generates a positive result and a negative result. The positive result is a function of the increase in its economic activity. So, as long as you receive all the profits from the increment, there will be a positive result. The negative result is a function of the additional overlap created by the increase in economic activity.

Thus, if the increase in economic activity makes it possible to obtain all the profits from the increase made, with the sharing of the negative effects of this increase (negative externalities) with society, the rational individual economic decision will be to increase economic activity, without worrying with the individual rational decisions of other human beings, who will also act in the same way in the most diverse economic activities, also generating positive results (profit), which will be internalized by them, and negative (negative externalities), which are socialized with the society. It was in this sense that Hardin dealt with the "The tragedy of the commons", according to him:

The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work reasonably satisfactorily.

Poaching, and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning, that is, the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the commons remorselessly generates tragedy. As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility to me of adding one more animal to my herd?" This utility has one negative and one positive component. 1) The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1. 2) The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any particular decisionmaking herdsman is only a fraction of -1. Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another... But this is the conclusion reached

by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit-in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all [24].

Each human being is contained in a system that drives him to increase his economic activity without limits - in a limited world of environmental resources. The tragedy is the destination to which all human beings are heading, each pursuing their own interest, regardless of the cumulative and synergistic effects caused by the sum of all decisions taken in isolation.

3. Results

Environmental risks, due to their transboundary nature, represent risks to the nature, economy, culture and politics of a society, therefore, they occupy a prominent place in discussions about social, environmental, political and economic issues worldwide, in terms of it concerns the distribution of environmental risks, together with the internalization of wealth by companies.

In this scenario, companies should be concerned with managing the positive and negative externalities of their production activities, as they are targets of public criticism, which can lead them, if they do not manage their externalities, to a reduction in their sales, due to the market losses.

For this reason, the choice of environmental risk management instrument is of paramount importance for the mitigation of the triple environmental responsibility of companies, since it will be the structuring of institutional arrangements - governance mode - that will allow the positive study of companies' strategies, enabling the reduction of environmental damage, and thus, consequently, the reduction of companies' environmental responsibility.

In the EIA, there are no follow-up and monitoring steps for the implementation of projects, nor is there a proper assessment of the effectiveness of measures to mitigate negative impacts, which prevents the proper and timely identification of adverse effects that were not foreseen by the licensing process environment and, as a result, allows the continuation of projects that are causing damage to the environment without proper mitigating consideration.

In this way, the EIA, as an environmental risk management instrument, because it is not subordinated to an institutional arrangement aimed at mitigating these risks, is limited to the specific verification of the environmental risks involved in a given project, ignoring the geographic context contained, for example, in regional development plans, watershed management plans, Ecological-Economic Zoning, Environmental Audits, environmental monitoring, among others.

However, as reported by Law and Economics, human beings, as rational beings, seek to maximize their gain (well-being). Thus, if the increase in economic activity makes it possible to obtain all the profits from the increase made, with the sharing of the negative effects of this increase (negative externalities) with society, the rational individual economic decision will be to increase economic activity, without worrying about the decisions rational individuals of other human beings, who will also act in the same way in the most diverse economic activities, also generating positive results (profit), which will be internalized by them, and negative results (negative externalities), which are socialized with society. This is precisely what the EIA-based environmental management model provides.

4. Conclusions

The industrial development and unrestrained demographic growth, coupled with widespread consumption and economic globalization, has led to a dizzying increase in the production of goods and services. Consequently, there was an increase in the demand for raw materials, which caused and has been causing indiscriminate exploration and pollution of environmental resources, leading to significant changes in the environment and increasing the risk of existence for living beings that inhabit planet Earth.

Sensitive to the issue of environmental risks and their consequences on the quality of life, the Brazilian Federal Constitution of 1988 dedicated an entire chapter to the protection of the environmental balance, raising the ecologically balanced environment to the category of a fundamental right, indispensable to the existence of a quality life. Since then, companies in Brazil have had a socioenvironmental function, expressed in meeting, in an egalitarian and supportive way, the aspirations of entrepreneurs and society reflected in obtaining profit through the production and circulation of goods and services. Services, and in the circulation of wealth, in accordance with the values of free enterprise, and in compliance with the limits determined by social concerns, reflected in the valorization of human work and in the defense of the environmental balance.

Therefore, companies also came to be understood as an instrument, whose socioenvironmental function is the realization and protection of fundamental rights, aiming to

enable the existence of a life worth living, through the realization of social justice, reflecting not only the economic factor, but also social and environmental factors. In this tuning fork, environmental risk, like so many other risks that permeate companies, must be considered when developing economic activity.

Thus, the existence of an institutional arrangement composed of risk and environmental damage management instruments able to act in the incorporation of negative externalities of the productive processes, since the beginning of its planning, can make the production of companies sustainable, generating a balance of market conducive to achieving the most efficient end to be achieved, namely sustainable development and, consequently, the protection of the environmental balance, right / duty provided for in Art. 225, *caput*, of the Brazilian Federal Constitution. In this context, the choice of the instrument for managing environmental risks and damages is extremely important.

In Brazil, Law No. 6,938/81 - National Environmental Policy Law - provides for EIA as one of its instruments. As a result, companies in Brazil, more often than not, aiming to comply with the provisions of that Law, adopt EIA as an instrument for managing environmental risks. It happens that, within the scope of the EIA, the environmental feasibility study is carried out after the decision to implement the projects already conceived, elected and prepared, lending itself only to legitimize the decisions of the entrepreneurs, with regard to the implementation of new processes. Productive processes or the expansion of existing production processes. Thus, the EIA does not have a preventive character, as it has no link with the process of design, election and project elaboration, that is, at the beginning of the decision cycle, but only has a link with the process of project implementation, or that is, at the end of the decision cycle.

The lack of integration of EIA into the planning phase of the decision cycle is due to a culture of business management, whereby the environmental variable is not included as one of the necessary factors to support the decision on the viability of the design, the election, design and implementation of projects, unlike the economic variable. In such a culture of business management, entrepreneurs understand the environmental variable simply as a restriction on economic activity and, therefore, on the viability of projects, which is why they adopt the EIA, postponing the analysis of the environmental variable until after the decision to implement it of the project, only to comply with legal requirements for obtaining or renewing environmental licenses, necessary for the beginning, expansion or continuity of economic activities.

Therefore, EIA does not take into account the cumulative and synergistic effects of environmental risks, represented by the sum of all environmental risks contained in the most varied economic projects existing in a state, municipality, neighborhood or river basin. With this, the EIA favors the so-called "tragedy of the commons", removing companies from the practice of truly sustainable economic activities, a fact that increases the risk of environmental liability and, with this, increases the risk of companies' reputation in the face of each market increasingly demanding when it comes to respect for the environment.

In this context, it is expected that Brazilian authorities and companies will adopt SEA as an environmental management model, in order to better delimit the environmental risks involved in the most varied production processes, in order to consider not only local impacts, but also but also the synergistic and cumulative impacts of the economic activities carried out, thus providing an early diagnosis of the environmental risks involved, which will be able to efficiently and effectively reduce the occurrence of environmental damage and, thus, reduce the possibility of environmental responsibility of companies.

Conflict of Interest

The authors declare no conflict of interest.

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EDITORIAL

Optimization by Hybrid/Combined Artificial Intelligent Models

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As *Journal of Management Science & Engineering Research* (*JMSER*) is oriented toward publication of high-quality research, which is focused on advancing practice through theory of operations management, thus, the *JMSER* aims to make a guide contribution to the management science and operation practice in today's global institutions. Along with the development of the artificial intelligence, accurate and precise forecasting results can be achieved. As the data may be with complexity, such as seasonality, cyclicity, fluctuation, dynamic nonlinearity, and so on, these forecasting models would suffer from the problem of inaccuracy while data characteristics and patterns are difficult to be determined. Therefore, hybridizing the artificial intelligent methods and superior meta-heuristic algorithms can improve the problem of inaccuracy, which is of great assistance to actions taken by decision-makers.

The so-called hybrid model, including hybridizing advanced optimization methods with meta-heuristic algorithms and evolutionary computation techniques in energy forecasting, which aims to attract researchers with an interest in the research areas described above. As Fan et al. [1-3] and Li et al. [4,5] indicate that there are three kinds of hybrid models: (1) hybridizing these artificial intelligent models with each other; (2) hybridizing with traditional statistical tools; and (3) hybridizing with those superior meta-heuristic algorithms to significantly improve forecasting accuracy. There are many relevant research papers in this new research trend. The editor believes that the hybridizing the meta-heuristic algorithms and artificial intelligent methods will receive more attention.

For **hybrid different evolutionary algorithms,** to concentrate the theoretical shortcomings of the meta-heuristic algorithms, by hybridizing artificial intelligent methods to adjust their embedded designs (e.g., mutation rate, crossover rate, annealing temperature, etc.) to receive

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more satisfied forecasting results, such as hybridizing grey catastronphe and random forest [1]; hybridizing simulated annealing algorithm and genetic algorithm [6]; and hybridizing wavelet transform and random forest [7]. For **hybrid different models,** to concentrate the worst disadvantage of each single model, which almost is its theoretical limitation, to integrate some additional process from other model into the conducting process, such as seasonal mechanism, by computing the seasonal index (*SI*) for each seasonal point in a dataset with seasonal period, then, calculating the forecasting value by considering *SI* [11-13]. The other hybrid model example is inspired from the concept of recurrent neural networks (RNNs) [14] and long-short term memory method [15-17], which employing past information to capture more accurate data patterns to improve the forecasting results.

On the other hand, the disadvantages of those artificial intelligent models are embedded in their theoretical design, such as premature convergence. Therefore, to overcome or to improve these drawbacks, it is feasible by conducting some theoretical arrangements to receive more accurate forecasting results. **Applications of chaos theory,** chaotized the searching variables into chaotic variables to comprehensively extend its searching space to increase the particle diversity [18], i.e., let variable travel ergodically over the searching space. Several adopting chaotic mapping functions can be employed to map the searching variable into chaotic variable, such as the Logistic mapping function, the Tent mapping function, the An mapping function, and the cat mapping function. **Using cloud theory,** cloud theory is a model of the uncertainty transformation between quantitative representation and qualitative concept using language value [8], like a fuzzy system in which the molecules move from large scale to small scale randomly as the temperature decreases. The cloud theory can realize the transformation between a qualitative concept in words and its numerical representation. **Applications of quantum computing mechanism,** the quantum computing mechanism (QCM) is used to quantize searching variables in a meta-heuristic algorithm, particularly the operation of quantum rotation gate can enable the particle to determine the most suitable rotation angle to escape from the local optimal solution to toward to its best solution. Many QCM trials have been proposed with meta-heuristic algorithms to improve the performances of the algorithm, such as the quantum PSO (QPSO) algorithm [19,20], the quantum bat algorithm (QBAT) [21], and the quantum fruit fly optimization algorithm (QFOA) [22]. In addition, the quantum rotation gate is also considered by the individual in the searching space to demonstrate the superiority of quantum behaviors [4,23,24] during the local searching process, to avoid trapping into local optima.

This discussion of the work by the editor highlights work in an emerging area of hybrid optimization methods with superior evolutionary algorithms that has come to the forefront over the past decade. These collected articles in this text span a great deal more of cutting edge areas that are truly interdisciplinary in nature.

Conflict of Interest

The author declare no conflict of interest.

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CASE REPORT

Application of Management Accounting in Company Sustainability

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ABSTRACT

This report illustrates how management accounting can be used in helping an organization reach sustainability by applying four main tools in management accounting to a dairy company. These tools are Life-Cycle Analysis, Identification of Relevant Costs, Activity-Based Costing (ABC) System and Balancing Score Card, all of which can help qualify and consequently quantify the various costs (including environmental costs) incurred during the operation of a company. Besides that, the above tools can also be utilised in a company's decision-making processes by the man-agement team. Thus, it is suggested that companies integrate these tools into their reporting system. This report illustrates the definition of a sustainable organization in the beginning, followed by detailed descriptions of the four management accounting tools, together with their applications to a diary company. The report ends with a summary on which type of role each tool plays in the re-porting system.

1. Introduction

Sustainability is a frequently mentioned word in the business environment nowadays. People are worried about this issue because the population keeps growing at a very fast pace and the consumption of natural resources has been skyrocketing, while the earth is a limited place. Therefore, in order not to leave our future generation a dreadful planet to live, we need to pay attention to the issue of sustainability so that the natural resources will be sufficient across every generation [1].

To make that happen, organizations have to make changes so that they can maximize their services and products with a given amount of resources, or minimize their resources used when providing the same level of products or services [2].

But in the meantime, organizations must not sacrifice too much since the existence of businesses is value creation and earning a profit. If companies are solely cutting their production for the purpose of environmental sustainability at the cost of making a loss, then such companies will go bankrupt very soon, resulting in a serious consequence of unemployment and economic recession.

Hence, we must define what is a sustainable organization, which is shown in Figure 1.

A sustainable organization must be profitable over the long run and generate an acceptable return for its shareholders to be economically sustainable. Socially, this

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organization must provide products and services that can be consumed by and add value to the clients in exchange for its revenue. In addition, this organization must provide employment opportunities for the society to uphold the organization's operation and to support the society's public stability. Lastly, during the daily operation, this organization must constantly improve its efficiency and reduce its pollution to become environmentally sustainable [3].

However, to improve an organization's sustainability, the management must know how to measure sustainability first. In other words, the transition from qualitative to quantitative factors. To achieve this purpose, management accounting serves as an indispensable tool for sustainability measurement.

Figure 2 shows the four main functions of management accounting that can assist.

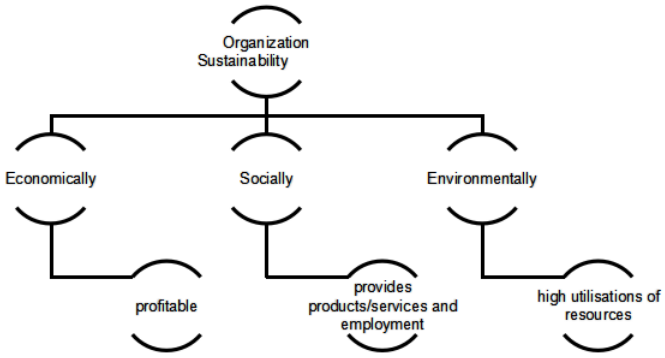

Figure 1. Components of organization sustainability

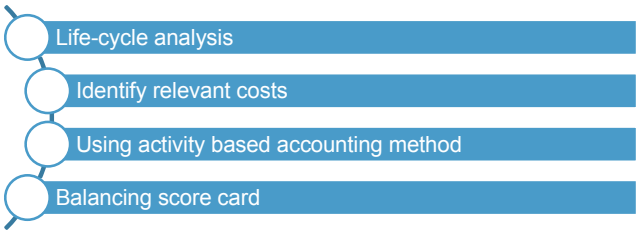

Figure 2. Four major functions of management accounting in assisting organization sustainability

2. Life-cycle Analysis

The life-cycle analysis can give us a clear picture of our company's overall activities. Moreover, it can help us identify the costs and benefits that can be incurred in each process and activity, which is also the second main function of management accounting [4].

As a management accountant working in the dairy industry, I will begin with a life-cycle analysis, which is illustrated in Figure 3, to identify what are the activities that our company has.

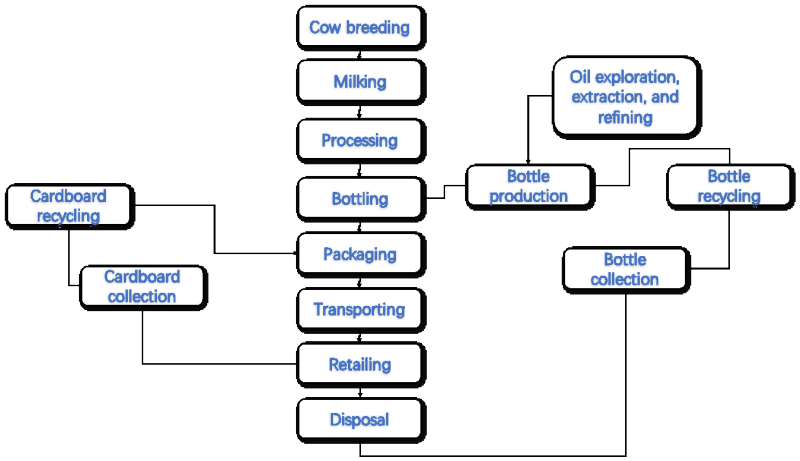

Figure 3. Life-cycle analysis of a dairy company

3. Identify Relevant Costs

After the life-cycle analysis of our company, we can now start to identify the relevant costs (mainly environmentally related costs) involved.

1) Cow breeding: The energy required for a milking cow is almost 4 to 7 times as much as it needs for maintenance. The excess nitrogen and potassium in forage can result in water contamination.

2) Milking: Milking machines and labor are required in this process. Thus, the electricity expense is the major cost as the machine has to keep running, and the labors need to manage the cows before and after they are milked.

3) Processing: A set of chemical and physical treatment is added to the raw milk, including disinfection, pasteurization, and separation before going further to the production of drinking milk, cheese, butter, or powder.

4) Bottling: A large amount of plastics is consumed in this process as bottles of the milk. The production of bottles requires the oil exploration, extraction and refining, which costs a great deal of energy and may cause pollution.

5) Packaging: Paper is the major raw material since every batch of products is stored in thick paper boxes. This process consumes a massive number of cardboard which are derived from plantation, deforestation and wood processing. All these activities might create noise and may damage the environment.

6) Transporting: Dairy products must be transported under low temperature to prevent spoilage. Hence, additional fuel expenses will be incurred to generate electricity for the low-temperature fridge on transporting vehicles.

7) & 8) Retail and disposal: After delivery and consumption of our dairy products, used cardboard and bottles become the main waste, which can be collected and recycled to reduce extra resources consumption.

Hence, to become a more sustainable company, we can focus on reducing the above environmental costs incurred during the life cycle of our business.

4. Using Activity-based Accounting Method

As a manufacturing company, our company's major costs involve direct materials, direct labors, and other manufacturing overhead cost. Both direct materials and labors are relatively easy to assign to our products as long as we can calculate the number of materials and labor hours used in each product line. In contrast, overhead costs are difficult to assign since these costs cannot be traced directly to our products. For instance, electricity expense of the processing factory is such an overhead cost that is hard to allocate. Traditionally, people would allocate this electricity expense evenly across different product lines. However, this method may cause the misleading cost allocation if milk powder requires much longer machine hours to produce, which consequently consumes more electricity than other products.

Therefore, to eliminate this erroneous overhead costs allocation, the method of activity-based costing (ABC) system can be utilized in our company. Instead of allocating this electricity expense evenly across different product lines, ABC system uses the drivers of the activities which give rise to the overhead costs as the basis of overhead cost allocation [5]. In the case of electricity expense, the underlying activity is the operating of a machine, and the cost driver of machine operation is the machine hours. Thus, we can allocate our electricity expense to different product lines depending on the machine hours they consume respectively.

According to this ABC system, our company's overhead cost pools and relevant cost drivers can be elaborated as follows in Table 1:

After obtaining the OH cost/driver, we can then multiply these unit OH costs by the number of units respectively, which can give us the following cost allocation in Table 2:

Table 1. Overhead costs and cost driving activities

Budgeted activities	Drinking milk	Butter	Cheese	Powder	Budgeted total OH cost	$	OH cost / driver
Feeding hours	82	56	77	8	Hay, grain & roughage	91,235	411
Watering hours	81	60	55	47	Water	632,214	2601
Number of fertilisation	69	59	57	73	Fertilizer	526,832	2045
Herding hours	80	8	4	5	Herding	701,540	7307
Number of vet visits	2	52	17	10	Vet & medicine	783,595	9714
Machine hours	12	5	75	70	Machine maintenance & depreciation	596,260	3669
Kilometers of delivery required	61	33	77	72	Delivery cost	12,987	53
Inspection hours	15	76	6	63	Quality control	20,967	131
Number of calls	78	49	92	8	Customer support	822,594	3631
Treating hours	17	55	26	1	Chemical treatment	373,575	3776
Treating hours	51	2	84	40	Physical treatment	138,101	778
Bottling machine hours	53	56	2	88	Bottling	902,281	4521
Packaging machine hours	56	96	88	11	Packaging	866,441	3459

Table 2. Allocation of overhead costs to different products based on ABC system

Budgeted total OH cost	Drinking milk	Butter	Cheese	Powder	Total
Hay, grain & roughage	33510	22833	31683	3209	91235
Water	211025	155776	144053	121359	632214
Fertilizer	140567	120728	116196	149341	526832
Herding	585972	54813	26350	34405	701540
Vet & medicine	23544	507184	160422	92445	783595
Machine maintenance & depreciation	44007	18489	276245	257519	596260
Delivery cost	3275	1753	4093	3866	12987
Quality control	1993	9965	734	8276	20967
Customer support	282956	176520	334340	28778	822594
Chemical treatment	64296	208440	97278	3561	373575
Physical treatment	39360	1841	65555	31345	138101
Bottling	240468	254779	10299	396734	902281
Packaging	193970	331045	303216	38210	866441

ABC system not only gives us a more accurate result regarding indirect costs allocation, but also helps the top management make decisions as to whether they can reduce certain activities that drive the costs to reach cost efficiency as well as environmental sustainability [6].

5. Balancing Scorecard

Now that the breakdown of overhead costs has been accomplished, and the cost structure for each product line can be illustrated clearly, top management may need to step in and make decisions around how to improve its status quo and become more sustainable.

A balancing scorecard is a superb tool in helping the top management with their strategy and decision-making [7].

To reach the financial target and create more wealth for our shareholders, our company must occupy more market share in the industry. So consequently, customer satisfaction becomes our company's priority. However, modern consumers are quite different to their counterparties decades ago. Nowadays, consumers care more about the quality of the products and the reputation of the brand, instead of only concentrating on the price. Hence, according to the balancing score card in Figure 4, our company could take the following steps to strengthen product quality and reputation:

1) Improve the employee' satisfaction first through employee suggestions, employee training, and employee safety and health as these activities will eventually push up employee productivity, which can, in turn, improve the product quality and its production cost reduction.

2) Control chemical usage in the internal process since the quantity of the chemicals can undermine the quality of our products.

3) Improve energy, water, and material efficiency through process monitoring and waste recycling. Such improvements can help reduce the relevant costs, and subsequently, demonstrate the image of a sustainable company to our consumers.

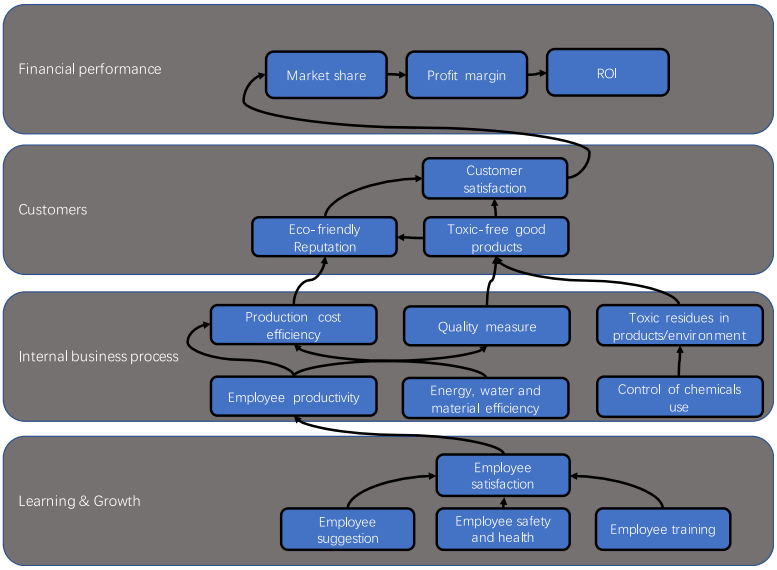

Figure 4. An example of the balancing scorecard of a diary company

6. Conclusions

To sum up, both life-cycle analysis and relevant costs identification enable the top management to qualify the various costs (including environmental costs) that may be incurred across the operation of our company. And the ABC system compliments life-cycle analysis and relevant costs identification by further quantifying those costs, which can provide the top management with detailed information. Finally comes the balancing scorecard, which can help the top management with strategy and decision-making to pursue a sustainable organization after the detailed information is available. Hence, it is strongly recommended that our company adopts these management accounting tools in our reporting system as they are beneficial to our company sustainability.

Conflict of Interest

There is no conflict of interest.

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ARTICLE

Study on Customer Demand Forecasting Models, Stock Management, Classification and Policies for Automobile Parts Manufacturing Company N.A.C.C. (An Advance on Classical Models)

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ABSTRACT

The primary intent of the current research is to provide insights regarding the management of spare parts within the supply chain, in conjunction with offering some methods for enhancing forecasting and inventory management. In particular, to use classical forecasting methods, the use of weak and unstable demand is not recommended. Furthermore, statistical performance measures are not involved in this particular context. Furthermore, it is expected that maintenance contracts will be aligned with different levels. In addition to the examination of some literature reviews, some tools will guide us through this process. The article proposes new performance analysis methods that will help integrate inventory management and statistical performance while considering decision maker priorities through the use of different methodologies and parts age segmentation. The study will also identify critical level policies by comparing different types of spenders according to the inventory management model, also with separate and common inventory policies. Each process of the study is combined with a comparative analysis of different forecasting methods and inventory management models based on N.A.C.C. parts supply chain data, allowing us to identify a set of methodologies and parameter recommendations based on parts segmentation and supply chain prioritization.

1. Introduction

With acute competition between economies, the necessity of organization, optimization of industrial processes, and management is essential to guarantee the evolution of companies due to the evolution of the triptych cost, quality, and service.

To be able to guarantee the optimization of one of the key functions in the logistics chain through industrial processes This word, logistics, whose Greek etymology is synonymous with logical reasoning, or mathematical cal-

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culation, was first used in military vocabulary to designate the coordination of transport, supply and communication activities in a war camp. Nowadays, there exist numerous ways to define supply chain management. It could be a process that involves activities to enhance a product or service from one state to another from the first supplier to a final customer. For better working order of products, the maintenance service is in charge of the designation of the activities. These operations often require the replacement of defective parts, hence the need for a stock of spare parts and therefore an inventory management process.

Traditionally, the management of these stocks is done by the maintenance technicians. However, this configuration does not allow a sharing of stocks and coordination of logistic activities, so it is now replaced by centralized management of the spare parts logistic chain which allows not only rationing of stocks, but also supervision and a mutualization of flows.

Spare parts management is within logistics and maintenance, with that being said it also permits to differentiate and compare to the classic case, which justifies the interest of its treatment by independent literature. Among these characteristics, we can distinguish the weak and erratic aspects of the demand. The highly significant and unpredictable demand forecast and inventory management have significantly impacted the general performance indicators in the supply chain: inventory levels and service. Moreover, the priorities between these indicators differ according to the segmentation of the parts and the customers of the chain, hence the need to take this differentiation into consideration when sizing the stocks. Thus, this article will analyze two issues such as forecasting and inventory management processes, before proposing improvements to their steps, to enable the establishment and integration and to permit the selection of newer prediction methods. At last, to bring up the unfamiliarity's of spare parts inventory management. In each phase of this article, the proposed processes will be analyzed using a design of experiments of real N.A.C.C. (North automobile components company) data and the results will be compared according to the segmentation of demand profile and the segmentation of parts maturity level.

This paper aims to ameliorate the responsiveness to the distribution of N.A.C.C. to great geographical demand by improving the internal inventory, in the case of a very large portfolio of references and a weakly controlled behavior of maintenance technicians, which requires the use of an approach based on the history of the demand rather than a reliability approach.

Thus, this research will analyze two forecasting and inventory management processes before proposing improvements to their steps, to establish a connection between the alternative processes and other methods, and to provide forecasting methods with a better understanding of the processes, it will be necessary to develop new approaches to forecasting. Ultimately, this will allow for a new approach to customer differentiation. In each part of the paper, we will go through data and experiments, finally, the maturity degree of parts will be compared based on their design and demand model.

2. Literature Review

In the following discussion, we will outline the definition of customer demand forecasting and highlight the current state of the art in research and build on it to expand on existing accomplishments.

2.1 Customer Demand Forecast

Forecasting is defined as the observation of a set of data that allows one to envisage a future situation and to undertake actions to deal with it concretely. Forecasting is the practice of estimating possible events or developments through the use of the past and the present as tools to estimate the future.

The task of forecasting is not merely to estimate potential future occurrences. "It also represents a principal input for decision support models, especially when it is a question of a very uncertain environment." A forecast is often required each time a decision is taken. "Forecasts are not meant to be used for their own sake, but to inform decisions." It is also used for the construction of anticipation strategies by companies.

Demand forecasting is a specific form of forecasting: "Demand can be described as the quantity of a good or service that people are wanting and willing to buy during a specific time frame"; "Demand forecasting is the science of anticipating the level of demand that may be expected to occur at a given time in the near or distant future". Demand forecasting can use methods, processes, and practices related to other types of forecasting (meteorological, econometric...), as well as using methods common to these types, known by their statistical efficiency such as smoothing methods.

To meet the specific requirements of the spare parts request described hereinafter, independent spare parts demand forecasting literature was developed and was dissociated from classical demand forecasting (such as product sales/purchase forecasting).

2.2 State of Art of the Research

An improvement of the Croston's estimator was done "*by simply adding a smoothing parameter for forecast-*

ing" Syntetos and Boylan (2007) [1].

After several tests some good results have been achieved when "*the bootstrapping method was applied to forecast component demand"* Willemain et al. [2].

"Grey systems theory has been employed to forecast material equipment in the Taiwan Navy" proving its effectiveness Chiou et al. [3].

Propositions of models based on "*support vector machines have been employed in several domains of forecasting"* such as (computing, motors, car parts etc…) which has also proven handy Hua Zhang [4],

Implementation of "*Neural networks have proven their effectiveness in forecasting auto parts, airplaine parts etc*…" it dealt with large scale data more effectively than most of the methods to forecast parts demand Gutierrez et al. [5].

The "*Kano model principle examined personalized demands, built a hierarchical model of personalized demands for products, and established the priority order of importance of personalized demand"* based on the hierarchical model and the ranking of importance, the customizable attributes of the product and their priorities for customization were determined (Tang Zhong-jun and Long Yu-ling 2012) [6].

"Large-scale spectral clustering with landmark-based representation selected K-means clustering of large customers" based on the dimensions of electricity, electricity prices, and capacity to classify customers into five categories. Second, customer requirements were identified based on large customer service orders, customer surveys, etc., and the requirements were hierarchically classified according to business types and customer perceptions. Finally, based on the findings of the customer cluster analysis, the specific electricity demands of customers in each category were identified, and demand stratification and resource allocation were proposed (Chen Xinsheng, Cai, D. 2011) [7].

"*System optimization method for customer demand prediction based on support vector regression analysis in the process*." They proposed three-step algorithm including mathematical model formulas of nonlinear programming (NLP) and linear programming (LP) to obtain the regression function, and the last step used a recursive method to predict customer demand effectively (Levi et al. 2005) [8].

"Demonstrations of the ability of self-organizing maps (SOMs) were used to classify customers and their responsiveness potential using merchants, trade, and customer flow demand databases, and helped load response modeling as supporting tools." "*Customer suitability searches are limited to daily and real-time products, and interest in such products is growing in developing countries. Therefore, customer demand and responsiveness (demand response and distributed generation strategies) were tested and compared to the price curve*."

The results significantly demonstrated the ability of the method to improve data management, and it is easy to find a systematic strategy to achieve clear demand ratios in different price scenarios (Valero et al. 2015) [9].

Studies have been done on the optimal inventory management of some companies. "*The price of products sold by the companies were driven by an exogenous stochastic pricing process"* that impacts the customer acquisition rate between ordering cycles, the author also analyzed the backlog and turnover of optimal ordering decisions. The research results show that the price-based inventory strategy is optimal under certain conditions (Canyakmaz et al. 2019) [10].

Based on the results of real Amazon datasets, forecasting the demand for remanufactured products is a complex nonlinear problem. "*With the help of advanced machine learning techniques, we can achieve highly accurate predictions of product demand"* (Truong Van Nguyen, Li Zhou et al. 2020) [11]. Another proposition to model customer demand using evaluation data has been made to firstly, address the concern that the number of issues in the clustering analysis is not easy to determine, a product performance Dictionary was provided to ascertain the clustering issues. The TF-IDF method was improved for the dictionary creation and based on product performance the dictionary completed customer demand mining. Secondly, in view of the lack of a demand analysis process in existing product review studies, a "*Kano analysis method based on product review data was proposed"*. On this basis, the matter-element representation was introduced to quantify the customer demand model (Wenxu Zhang; Renbin Xiao; Wenguang Lin 2019) [12].

Most of these works used statistical models for demand prediction. "M*achine learning approaches have achieved promising results in time series forecasting over the past decade*." This trend is not recognizable for automotive spare parts demand forecasting, which is a related field. Despite the advantages, the overall picture of customer demand forecasting methods influenced by improved classical methods still remains unclear according to Borempi et al. (2017) [13].

This motivates the identification of automotive component time series characteristics to conduct a literature review to determine possible approaches applicable to the spare parts demand forecasting problem. To bridge this knowledge gap, this survey aims to explore ways to improve classical forecasting and inventory management models in terms of improving customer forecasting.

3. Research Method

As such, a well-functioning spare parts supply chain is mandatory to maintain the accessibility of spare parts to help technicians by providing alternative transportation and storage facilities while optimizing and streamlining inventory.

The planning team is responsible for centralized inventory management. Its tool provides plans based on forecasts to the procurement staff. One of the first things that stand out of our analysis is the need to standardize practices which today are too often based on individual initiatives that do not offer the control of the spare parts management and distribution process desired by the company. This standardization of practices, to be adopted and effective, should not be positioned in total rupture of practices, especially since the experience of the suppliers remains preponderant. Thus, from our point of view, the standardization of these practices will have to be based on a rationalization of current practices in terms of spare parts inventory management.

An additional point that we can emphasize here is that, although the amount of data that supply houses have to deal with, the volume of data dedicated to the handling of a reference is very limited and their volatility is significant. The accuracy of the forecast estimates of each reference is then significantly affected. Such as in the below (Figure 1).

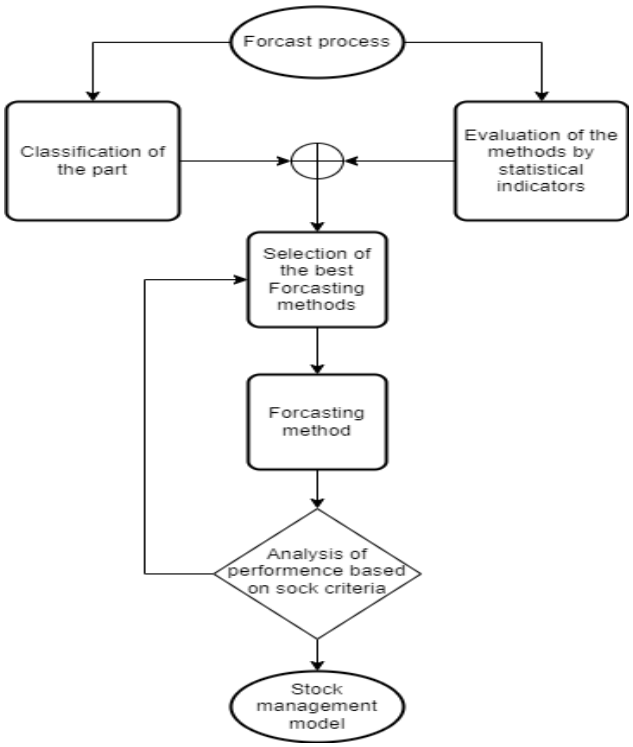

Figure 1. A classical approach to assessing the performance of forecasting methods

Demand forecasting is among the most challenging aspects of inventory management, particularly for spare parts. In fact, in this context, it is essential to precisely estimate the appearance of demand: an under-estimate causes almost immediate stock-outs (and consequently a significant outage time of the process), Over-estimation entails high capital costs and risks of obsolescence due to very weak demand. In addition, the demand for spare parts is related to product failure or a certain preventive maintenance strategy. In our case, linking the process of characterizing the demand for spare parts to reliability analysis of the products does not seem to be realistic, because of the internal practices of all the actors in the supply chain, as well as the usage behaviors of the customers, are poorly controlled. Therefore, we propose to focus our literature review on demand forecasting models using an approach based on historical demand, in order to improve inventory management. In regard to measuring the outcome of the forecasting model in the case of spare parts, a commonly proposed process is comprised of three phases.

The focus of this subsection below is to address the latter three by highlighting the limitations of existing approaches for each approach. Then, we will derive from this analysis a proposal for improving this process, in particular by taking into consideration the level of maturity of the parts, the suggestion of a hybrid forecasting method, and the development of indicators allowing a choice of forecasting methods in function of the risks involved in the management of the stocks.

This part will conclude with a comparison of the selection of forecasting methods by different performance indicators and by different classifications of N.A.C.C. spare parts data.

3.1 Improvement of the Classical Spare Parts Forecasting Methods Process

In the following, we outline the advancements, that we do at all stages of the forecasting process.

- The “pre-processing” stage, allows us to sort the requests based on the frequency and the degree of this demand.

- “Processing”, which defines the forecasting methods to be used.

- The “post-processing” is the same as the evaluation of the efficiency of the adopted model.

- This stage involves the elaboration of the data in order to develop the appropriate forecasting algorithms.

3.1.1 Pre-processing Stage: Consideration of Criteria Extension

However, this is often limited to a classification of the

type of demand and parts, while neglecting other essential aspects such as the definition of the type of history to be used as well as its size. To broaden this pre-processing step we consider these features in Figure 2.

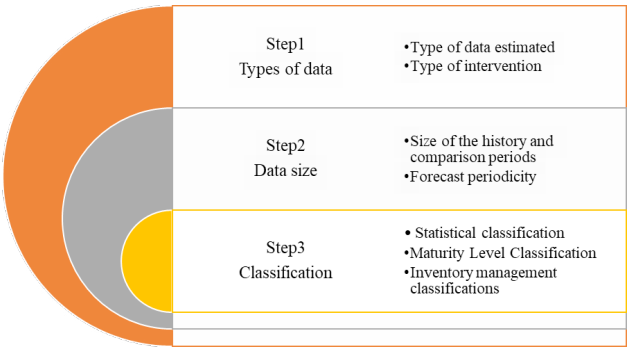

Figure 2. Novel pre-processing chart

The pre-processing step is accordingly split sequentially into three sub-steps:

Sub-step 1:

So, in the following section, we discuss the various types of forecasts that can encompass the inventories of a spare parts supply chain.

Sub-step 2:

We choose the size of the input data: this includes the size of the history to be used, the size of the comparison between the models, and the periodicity of the forecast.

Sub-step 3:

We list the set of spare parts criteria that can have an influence on the forecast and we define an adequate classification for our problem. When forecasting a spare part reference (processing), this classification will not only allow us to select the forecasting methods to be tested for this reference.

When forecasting a spare part reference (processing), this classification will not only allow to select of the forecasting methods to be tested for this reference but also to use the data of similar references (of the same class), to define the selection procedure of the best forecasting method and to designate the appropriate measures for this reference.

Sub-step 1: Data type

In this section, we detail the data types that can be used for pre-processing. These are focused on the types of demand generated and the response required.

Type of demand that has been generated, there exists four major types of demand generation:

1) The actual demand, which accounts for the actual overall needs of the maintenance technicians.

2) Productivity: Estimates of spare parts productivity flows refer to the creation of added value in parts without the need to purchase new parts from suppliers. This can include warehouse repair capabilities of parts, reclamation of refurbished parts from old systems, exchange of defective parts under warranty, etc.

Substep 1: Type of intervention

The traditional method of forecasting is to utilize a unique forecast independent of the operation type; an alternative approach involves separating the inputs by operation type into this estimate. so we can distinguish:

Installation intervention is related to the replacement of parts during the installation of systems. Often, this is not a failure to use the system, but a malfunction due to handling or installation problems.

Corrective maintenance intervention is related to the replacement of parts following breakdowns.

Intervention for systematic preventive maintenance, which is the replacement of parts on the basis of time conditions.

These different types of interventions have different degrees of difficulty in estimation. For this reason, the assessment of the frequency of the demand is much easier in the context of predictive maintenance than corrective maintenance. Moreover, this can lead to different requirements regarding the availability of parts.

Substep 2: Data size

After defining the types of data to be used in the forecasting process, the next step is to define the amount of data to be utilized in forecasting models and intercomparisons:

- The size M of the history to be used in the forecasting algorithms.
- The size N of the forecasting behavior simulation.
- The size N of the simulated demand forecasting behavior for performance measurement.
- The periodicity P of the forecast: Monthly, Quarterly, Yearly.

Substep 3: Classification of a spare part

Several classifications can be used in the case of spare parts. Indeed, a classification can be used as long as it is relevant for instance whether it impacts the database pattern, the prediction outcomes, the choice of prediction models.

Contrary to the literature which often limits itself to a statistical classification to select a set of forecasting methods, we list here other types of classification which can strongly influence this selection such as the level of maturity of the part in its life cycle or criteria related to inventory management (such as the cost of the part for example).

Statistical classifications

Several types of statistical classifications can be distinguished. They are obtained by a statistical analysis of the history of the demand. We identify the various criteria as follows:- Significance of the demand: High demand/Medium demand/Low demand.

- Correlation of demand: High correlation/Low correlation/Positive correlation/Negative correlation. This is calculated by the correlation coefficient.

- Demand Interval: Large non-zero demand interval / Small non-zero demand interval (measured by A automatic D demand I interval).

- Demand variability: Variable demand/stable demand. (Measured by CV).

Classification by part maturity level

The pattern of demand can vary significantly based on the maturation level. Therefore, a classification taking into account these aspects may be necessary. We mainly find the three following maturity phases: Introduction phase, Maturity, End of life.

Installed base

The size of the installed base (number of products sold for a given system) has a significant influence on the frequency and size of the demand for spare parts for this system. In another way, the system's life span may also have a significant impact on the demand profile created. Additionally, the degree of innovativeness of a newly installed base can affect the requirement for spare parts. It is possible to therefore introduce the following three classifications: Installed base categories: Large base, Medium base, Small base.

A. Product life phase categories: Launch, Saturation, Decline.

B. Level of innovation of the installed base: High, Medium, No innovation.

C. Inventory management characteristics. These characteristics are normally used to define the parameters of inventory management models. Usually, they only come into play from the inventory management process. However, considering our objective of building an inventory management-oriented selection approach, it seems logical to make them intervene in the forecasting process. Thus, they will have an impact according to the priorities they translate into stocks or service levels, which will better reflect the objectives we have set in terms of stock management performance. Among these classifications we can distinguish for example:

- Classification of the part price: Cost classification A/ B/ C.

- Classification of the part criticality to the system: Vital v/Essential e/Desirable d (v.e.d).

Further detail on these inventory management classifications will be included in Chapter 5, which presents the inventory management process, specifically the inventory management classification step. See the classifications in the below (Table 1):

The boundaries between the categories of the identified classifications are established based either on suggested boundaries in the literature or on the findings of experiments.

Table 1. Overview of categories for spare parts forecasting

Classifications	Category 1	Category 2	Category 3	Category 4
Significance of the demand	Low	Average	Important	
Coefficient of correlation	Low negative	Low positive	Strong negative	Strong positive
Statistics (retained ADI/CV)	Stable	Intermittent	Lumpy	Erratic
Level of maturity	Introduction	Mature	End of life	
Technical classification 1 (cost)	A	B	C	
Technical classification 2 (criticality)	Vital	Essential	Desirable	
Installed base	Low	Average	Important	
Life cycle of the installed base	Launch	Saturation	Decline	
Level of innovation	No innovation	Slight	High	

3.1.2 Illustration of Hybrid Methods

Why a hybrid forecasting method?

A hybrid forecasting method allows a combination of the characteristics of the forecasting methods used in this approach. For example, it can combine the results of the smoothing principle of one method with those of the averaging principle of another. Moreover, in most cases, there is no method that completely outperforms the others. Thus, this combination may allow the best method to be reinforced by the performance of the others.

3.1.3 Implementation of Hybrid Method for Improvement

The processing step: Hybrid methods

Why a hybrid forecasting method?

A hybrid forecasting method combines the properties of the forecasting approaches in this study. For example, it can combine the results of the smoothing principle of one method with those of the averaging principle of another. Moreover, in most cases, there is no method that completely outperforms the others. Thus, this combination may allow the best method to be reinforced by the performance of the others.

3.2 The Two Hybridization Approaches Proposed

In this section, we propose two methods for hybridizing N forecasting methods.

In the following we will use the notations given in Table 2:

3.2.1 Hybridization Method 1

The idea behind the method is to provide a non-zero weight to the methods according to their performance in each historic period. The use of these weights will make it possible to combine all the methods which were dominant over at least one period. We will use the following additional notations in the following (Table 3):

The following pseudo code describes how to evaluate the weight of each prediction method:

Algorithm 1

```
For i from to 1 to N

End For
For t ranging from 1 to H
   For i ranging from 1 to N

   End For
   For i ranging from 1 to N
         Best=true
         For j ranging from 1 to N
              IF ( then
                        Best=false
              End if
         End for
         If better then

         End If
    End For
End For
```

The forecast obtained by the hybrid method 1 (Hy 1) at period H for period $\boldsymbol{H+t}$ is:

3.2.2 Hybridization Method 2

For this method, we introduce a memory effect by defining transition probabilities from one method to another. That is, unlike the previous method, we take into account for each period the performance history of each method in that period but also in the previous period and we count the number of times there is a transition from one method to another in terms of dominance. The following additional notations are used (Table 4).

Table 2. standard notations for both hybridization approaches

Notation	Signification
N	: Number of forecasting methods to hybridize
H	: Size (in number of periods) of the history used
D_t	: Demand at period t
$F_i^j(t)$	: Forecast made at date j for period t by the method of forecast i, $(i,t) \in [\![1,N]\!] * [\![1,H+1]\!] (i,t) \in [\![1,N]\!] * [\![1,H+1]\!]$
$SE_i(t)$	: Error calculated at period t by the forecasting method *i*,

Table 3. Notation for hybridization approach 1

Notation	Signification
P_i	: Weight given to the forecasting method *i*

Table 4. Notation for hybridization approach 2

Notation	Signification
P_{ij}	**:** Transition probability of forecasting methods ***i to j, (i, j)***
	: Transition counter for forecasting methods ***i to j, (i, j)***

The following pseudo code describes how to evaluate the different transition probabilities:

Algorithm 2

For *i* from to 1 to *N*
For *t* ranging from 1 to *N*

End For
End For
For *t* ranging from 1 to *H*
For *i* ranging from 1 to *N*

End For
For *i* ranging from 1 to *N*
For *j* ranging from 1 to *N*
IF **[(**
Then

IF not
IF [(Then
If better **then**

IF not
If [(
Then

If not
If [(
Then

If not

End if
End if
End if
End if
End if
End if
For *i* from to 1 to *N*
For *i* from to 1 to *N*

End For
End For

To obtain the forecast by the hybrid method 2 at period H + t, based on the method j that has been best evaluated over period H (the lowest (H)) we will calculate:

Impact of the two approaches:

In what follows, we present two simple estimates to explain the impact of the two approaches.

Example 1: We take the case of part A on a 6 months history (January to June). We also know the forecasts that have been made on the history and we study the behavior of the hybridization method 1. Table 5 summarizes the input data considered.

Table 5. Input data for illustration 1

	Jan	Feb	Mar	Apr	May	Jun
Demand	4	5	4	6	4	5
Forecast Method 1	3	4	4	4	3	3
Forecast Method 2	6	5	5	5	7	6

If we evaluate the two forecasts by a classical statistical indicator (mean square error), we obtain mse1 = 1.83 and mse2 = 2.66, which indicates dominance of method 1. However, we note that forecast 1 tends to underestimate demand, unlike forecast 2. Let us now use the hybrid method 1 whose results are given in Table 6.

Table 6. Results obtained by hybridization approach 1

	Jan	Feb	Mar	Apr	May	Jun
P_1	1	1	0.5	0.67	0.5	0.6
P_2	0	0	0.5	0.33	0.5	0.4
Forecasts Hybrid Method 1	3	4	4	4	5	4

When we proceed, we obtained statistical indicators, such as m.s.e hyb1= 1.33. It can be seen that we have been able to considerably improve the prediction quality and if we analyze the outcomes, we observe a diminution of the tendency to underestimation or overestimation. Example 2: We take the case of part B over a 5-month history (January to June). In this history, we notice a strong increase in demand over the last two periods. We also know the forecasts that have been made on the history, we study the behavior of the hybridization method 2. Table 7 summarizes the input data considered.

Table 7. Input data for illustration 2

	Jan	Feb	Mar	Apr	May	Jun
Demand	3	2	3	4	8	10
Forecast Method 1	2	2	1	3	5	6
Forecast Method 2	7	5	5	5	7	8

If we evaluate the two forecasts by a classical statistical indicator (mean square error) we obtain m.s.e1 = 5.66 and mse2 = 6.66, which indicates dominance of method 1. This method should therefore naturally be preferred. However, we note that forecast 1 tends to underestimate demand, unlike forecast 2, but that the latter reacted better to the sudden increase in demand. Let us now use the hybrid method 2 whose results are given in Table 8.

Table 8. results obtained by the hybridization method 2

	Jan	Feb	Mar	Apr	May	Jun
N_{11}	0	1	2	3	3	3
N_{12}	0	0	0	0	1	1
N_{21}	0	0	0	0	0	0
N_{22}	0	0	0	0	0	1
P_{11}	1	1	1	1	0.75	0.75
P_{12}	0	0	0	0	0.25	0.25
P_{21}	0	0	0	0	0	0
P_{22}	0	0	0	0	0	1
Forecasts Hybrid Method 2	2	2	1	3	6	8

Calculating the statistical indicators obtained, we have msehyb2=2.33. We can observe that also the accuracy of the forecast has improved significantly and when we consider the results, we have a diminution of the underestimation or overestimation tendency. Additionally, we observe how the hybrid method has adjusted to high fluctuations in demand.

4. Classification for Classical Methods of Spare Parts Demand Forecasting

We use the following classifications:

- the statistical classification of demand;
- the classification of the maturity of the part;
- inventory management classifications to give stock/service priorities.

The innovativeness of the chosen classifications is in contrast to the classical experiments in our literature. We are also using the part maturity classification in our case; we shall test the selection of the method depending on the degree of maturity. Moreover, we also use the classifications in inventory management of the part such as its criticality or its price, this will allow judging the weight to be given by the decision.

-makers to the selection measures;

-the thresholds of the classifications;

-the statistical classification of demand.

For this classification, we retain the thresholds suggested by the literature. For the demand interval threshold: automatic demand interval=1.33 it separates between high and low-frequency demands. For the demand variability threshold: cv2=0.49 it separates between low and high variability demands.

Part maturity classification: the classic way to have a part maturity classification is based on: design and life cycle studies within the conception process of a part. Reliability data of the part and the type of the part (mechanical/electrical...) by sampling on parts already in use. To accomplish this, we are basing the simulation on a great number of references from the N. A. C. C. Databases. Using a wide range of resources will allow us to assess the structure of the demand depending on the degree of maturity of the part. The following (Figure 3) is the graphic evolution of the demand based on the maturity of the part.

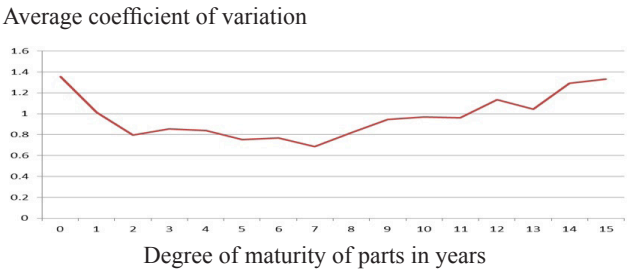

Figure 3. Development of the evolution of the demand as a result of the degree of maturity of the parts.

The below (Figure 4) is the graphic evolution of A.D.I based on the maturity of the part.

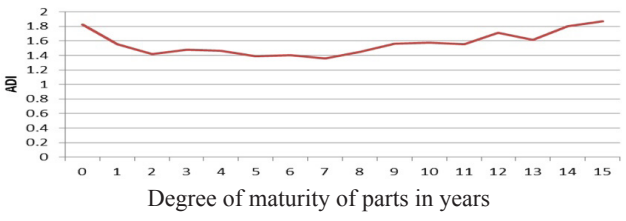

Figure 4. Evolution of the average demand interval according to the maturity level

The distinctions in the maturity levels of these two charts between two successive points are as follows Table 9:

Table 9. Degree of maturity Variation Divergence in automatic demand interval

Maturity degree	Variation divergence	Divergence in Automatic demand interval
0 → 1	–0.34	–0.28
1 → 2	–0.22	–0.13
2 → 3	0.06	0.06
3 → 4	–0.01	–0.01
4 → 5	–0.09	–0.08
5 → 6	0.01	0.02
6 → 7	–0.08	–0.04
7 → 8	0.13	0.09
8 → 9	0.13	0.11
9 → 10	0.02	0.01
10 → 11	–0.01	–0.03
11 → 12	0.17	0.16
12 → 13	–0.09	–0.09
13 → 14	0.25	0.18
14 → 15	0.04	0.07

Both charts indicate that the pattern is in a curve in respect of both the demand variability standard and the average interval between requirements standards. However, this correspondence with the bathtub curve is clearer by the demand variability criterion. The numerical comparison of the transition gaps (Table 9) between the various maturity levels in years approves this graphical analysis and helps to identify the inflection points of these curves. The progression from 2 years to 3 years: indicates the completion of a declining trend in variability and automatic demand interval of demand that originated at a very high degree in the initial year. Thus, the shift to a more stable period. The transition from 7 to 8 years: identifies the end of a stable evolution of the level of variability and the automatic demand interval, towards an upward trend in these two statistical measures. We can therefore find the three classic maturity levels of spare parts, by identifying them by thresholds. Thus, we will retain the following thresholds:

- introduction: between 0 and 2 years.
- maturity: between 3 years and 7 years.
- end of life: more than 8 years. Processing stage in the interest of conciseness, we restrict the analysis to the use of 4 forecasting methods:
- the moving average (ma) method as representative of methods with an averaging principle.
- the simple smoothing method (ses) as representative of the methods with a smoothing principle.
- the Croston (cr) and it's variant (sba) methods as representative of the methods with a double quantity and interval prediction principle.

We will evaluate in a dedicated part the contribution of the hybrid methods proposed (hy1) and (hy2). Post-processing step we contrast the resulting separations by the following measures: - the mse measure is typical of those statistical selection measures. The mse measure is representative of statistical selection measures.

- the LTFE measure takes into account the supply time, with 4 scenarios: lt= {1,3,5,8} months.
- ioe measure takes into consideration the tendency to overestimate or underestimate demand and the risk of overstock and shortage of stock, with 2 scenarios: one = 0. To prioritize stock at the service level. This can correspond to a classification of low-cost parts and high criticality. Conversely = 0. 3 a stock priority can correspond to a classification of high-cost parts and high-criticality parts with the high cost and low criticality.

4.1 Results of the Comparison of the Selection by Classifications with the (LTFE, MA, SES, CR, SBA) Methods

We run a test of the above experimental design on data obtained from the N.A.C.C.

This database consists of requests for 1500 spare part references.

We represent the results in a percentage of selection of each method against the demand profile classification and then against the spare parts maturity level classification. In addition, we display the findings in a way that allows us to measure the impact of the change in the lead time, as well as inventory or service prioritization.

Selection Results by Demand Profile Segmentation Impact of Supply Time

The following (Tables 10, 11, 12, 13) will classify the results of different demand profiles below.

Stable parts

Table 10. Sampling according to the supply time for stable parts

LTFE	LT = 1	LT = 3	LT = 5	LT = 8
MA	68.2	65.6	62	59.4
SES	5.4	6.4	6.8	7.4
CR	8.2	10	10.2	12
SBA	18.2	18	21	21.2
Total	100%	100%	100%	100%

Sporadic Parts

Table 11. Sampling according to supply time for sporadic parts

LTFE	LT = 1	LT = 3	LT = 5	LT = 8
MA	6.4	33	19	18.4
SES	3.8	9.6	25.4	30.2
CR	26.6	18.8	17.8	15.8
SBA	63.2	38.6	37.8	35.6
Total	100%	100%	100%	100%

Erratic Parts

Table 12. Sampling according to the supply time for erratic parts

LTFE	LT = 1	LT = 3	LT = 5	LT = 8
MA	23.6	24	30.6	42
SES	28.6	42.6	51	39.2
CR	23.2	25.8	7.8	8.4
SBA	24.6	7.6	10.6	10.4
Total	100%	100%	100%	100%

Summary of method performance

Table 13. Sampling of the selection according to the supply time by demand category

Supply time / Demand category	Supply time Short	Supply time Long
Stable	1. MA	1. MA
	2. SBA	2. SBA
Sporadic	1. SBA	1. SBA
	2. CR	2. SES
Erratic	1. SES	1. MA
	2. SBA	2. SES

The results first confirm the results of the literature, concerning the adaptability of the Croston variants for sporadic parts, the moving average variants for stable parts, and the smoothing method variants for parts with high variability.

However, the main added value of this analysis by the long-term forecasting error measure is that while for stable parts the sensitivity to the length of supply time is low, it is significant for sporadic and erratic parts. Indeed, the distribution of the selection changes significantly for these last two categories when the supply time increases.

Hence, the usage of the spare part supply time data will be suggested in the choice of the forecasting methods for sporadic or erratic parts. For stable parts, the use of this piece of data is not essential.

In this chapter, we have provided input into the spare part demand forecasting process with the goal of matching the points that have been identified in the spare part analysis.

The goal of this chapter is to match the points identified in the analysis of the spare parts forecasting and inventory management issue in Chapter 3.

Indeed, these contributions extend the classification of spare parts in this setting, particularly by considering the maturity degree of the parts. They are based on the historic demand forecasting models. They consider the weak and erratic aspects of demand in the selection approach and propose new selection measures that allow the first consideration of inventory management priorities. The results of an experimental design based on these proposals demonstrate the relevance of segmentation by maturity degree of spare parts in the choice of forecasting methods. This analysis also justified the need for the proposed measures that often select different methods based on the length of the supply time and on stock or service priorities.

Finally, an analysis of the performance of the hybrid forecasting methods proposed by our work showed a good quality of its second configuration and that its performance can vary depending on the class of the part.

Yet, given that the optimal goal of a full inventory management process based on forecasting is the improved management of inventory, service level, and inventory level indicators, it is essential that the forecasting process be implemented in a way that is efficient and effective, this implies a need for integration with inventory management policies in order to evaluate the forecasting methods by the final indicators of inventory management.

4.2 Improvement of Inventory Management Methods

In this section below we will identify the types of inventory management methods and consider improvements as well.

4.2.1 Types of Inventory Management Methods Types of Reviews

(1) Periodic review (R, Q)

With T periodicity $T \in N$, if the present period is $N \times T$ with $N \in N$ the stock level is being measured, if it is less than R an economic quantity order is placed to attain the Q level.

This gives a good synchronization of orders and tracking, but its major disadvantage is the inability to react and the lack of full traceability during the given period.

(2) Continuous review (s, S)

The logic of this policy is to monitor the state of the stock in a continuous way. Once the stock level decreases below s, an order is issued to attain level S.

This policy allows more reactivity to the variability of the demand and the reduction of the time of shortage of stocks.

4.2.2 Types of Order Quantities

Inventory management policies use two types of order quantities.

Fixed quantities

In this case, the model always places an order of the same quantity, this may be due to constraints imposed by the supplier or in the case of very stable demand.

Variable quantities

In this situation, the model issues an order that may fluctuate from period to period, thus requiring a certain amount of flexibility from the supplier. This approach is often advisable in the instance of variable demand.

Thus, four types of inventory management policies can be identified according to the two types of stock review and order quantity (Table 14).

Table 14. Varieties of Inventory Management approaches

When / How much	Periodical review	Continuous review
Fixed quantity	Calendar method	Control point method
Variable quantity	Replenishment method	Replenishment to order

In terms of spare parts, the ongoing service and variable volume "make-to-order" policy is the most suitable due to its responsiveness to varying demand and the critical aspect of the breakdown which requires more reactivity of supply.

4.2.3 Order Management Mode

Lost Sales: LS order management mode

In such a case, if an order is not satisfied by the stock, then it will be canceled. This pattern occurs in the situation where there is a stock of finished products or no existing contract, or where there is a risk of a stock-out.

Backorder: BO

In this case, if a request is not satisfied from the stock, then the request remains on hold, it is said to be in "backorder".

The Backorders scheme is most commonly encountered in the case of managing spare parts for equipment, because of the difficulty of finding a replacement from the competitor and because often a contract is established with the customer.

4.3 Application of the Improved Inventory Management Models Based on Forecasts

A majority of the model literature is focused on a demand hypothesis or on probabilistic demand flow scenarios.

Simultaneously, specific literature suggests forecast-based inventory management strategies and highlights their contrast with demand-based inventory policies. Indeed, these models use an estimation of the inventory projection by forecasting calculations in the supply logic, integrating the forecast error in the calculation of the supply thresholds which are often dynamic according to the variability of the forecasts over the next periods.

Since our work is focused on a forecasting approach for spare parts, and our goal is the connection of the invento-

Table 15. Ratings

Notation:	Meaning.
L	**:** supply time
$F_{i+k}^{(i)}$	**:** Forecast made at period i for period i + k
$f^{-1}(\propto)$	**:** the theoretical risk of inventory shortage $\propto$ on L, with the theoretical service level SL=1-$\propto$
	: The calculated forecast error on the start of period i
M	**:** The average demand
	: the standard deviation of the demand
T	**:** The stock review period, with T=1 if the review is continuous
H	**:** The desired duration of coverage by the stock
OC	**:** the cost of placing an order
UC	**:** the unit cost of the spare part
HR	**:** the inventory holding rate

ry management process with forecasting in the upcoming chapter., we will therefore use models based on forecasts.

How much Periodical review?

Continuous review; Fixed quantity calendar method; Control point method; Variable quantity replenishment; Method replenishment to order.

So, taking the ratings in Table 15 as a starting point, we provide the threshold calculations for these models in the following table, while emphasizing they differ from the demand-based ones.

Thus, inventory management policies are constructed by combinations between the thresholds in this table, for example:

The policy (SI) represents the continuous review and variable quantity policy, at each point in time in the period I if the stock level is below the level if an order is placed to reach Si.

4.3.1 Indicators for Evaluating Inventory Management Models (Service Level Assessment)

The inventory management service level is linked to the stock availability degree, meaning its failure to satisfy a customer's demand by the supply, in the present case it is a failure to satisfy a demand of the maintenance technician.

This level of service can be in quantities or in periods. We consider the case of inventory management with backorders.

We present performance evaluation measures over N periods using the notations in Table 17:

Quantity measures:

The quantity of service level is:

$$QSL=\frac{\sum_{i=1}^{N} Di-\sum_{i=1}^{N} BOi}{\sum_{i=1}^{N} Di}$$

Measurements in periods:

A further measure related to the level of service can be the amount of time that back orders occurred.

If BO $L_i > 0$ then, Pi=1; If not Pi=0.

The level of service in periods is:

$$PSL=\frac{N-\sum_{i=1}^{N} pi}{N}$$

4.3.2 Evaluation of the Stock Level

The evaluation of the stock level is done by measuring it in quantity, by measuring the inventory value during the inventory is measured in quantity, or by measuring the inventory value during the comparison period.

Inventory Level:

$$IL = \frac{\sum_{i=1}^{N} OH_i}{N}$$

Inventory Value:

An alternative measure often applied in this context is the measurement of inventory to demand (or inventory turnover), which provides a reference of this level and thus allows for the comparison of inventory levels among

Table 16. Comparison of forecast and demand inventory management policies

Approach / Model thresholds	Model On request	Model On forecast
Safety stock ss	**ss=$f^{-1}(\propto) * \sqrt{L} * \sigma$**	**ssi=$f^{-1}(\propto) * \sqrt{L} * \sqrt{MSEi}$**
Control points	**s=ss+M*L**	**si=ssi+$\sum_{k=0}^{L-1} F_{i+k}^{(i)}$**
Periodicity of review P	**N*T**	**N*T**
Completion level S (or R depending on the notation)	**S=ss+M*(L+T)**	**Si=ssi+$\sum_{k=0}^{L+1} F_{i+k}^{(i)}$**
Economic quantity Q (according to Wilson)	**Q=$\sqrt{\frac{2*oc*M*H}{HR*UC}}$**	**Qi=$\sqrt{\frac{2*oc*\sum_{K=0}^{H-1} F_{i+k}^{(i)}}{HR*UC}}$**

Table 17. Ratings for the performance evaluation of the inventory management model

Notation	Meaning.
O	: The inventory at beginning of a period i
D_i	: The demand at period i
BOi	: The amount of backorders that result from the simulated inventory during period i

parts of different types or volumes of demand.

Relative Inventory Level:

$$RIL = \frac{\sum_{i=1}^{N} OH_i}{\sum_{i=1}^{N} Di}$$

Synthesis and improvement

Thus, we summarize what has been presented above by a three-step process of inventory management on forecasts (Figure 5):

The initial purpose of the first step in the above process is to establish the service level to be applied in the inventory management model. Very often a service level matrix is defined, based on the objectives of the decision-makers in service and the budget.

Example: the case of classification in criticality and cost (Table 18).

Table 18. Sample of a service level matrix by inventory management classification

Criticality	Vital (V)	Essential (E)	Desirable (D)
High(A)	95%	94%	93%
Medium (B)	97%	96%	95%
Low (C)	99%	98%	97%

However, if we want to reach for example a 95% service level for the category (Vital (V), High (A), this can be equivalent to using a 99% service level for sporadic parts and 95% for stable parts. Indeed, as the demand for spare parts is highly unpredictable, the assessed service level can be entirely unrelated to the predefined theoretical service level.

In this sense, although they have an impact on the quality of the forecasts and consequently on the measured service level, the classifications of spare parts in the spare parts demand profile and the maturity degree of the parts have not been employed for the determination of this service level of the forecast-based inventory management model and its associated use was limited to the forecasting process (forecast method selection).

We employed an experimental design based on these two classifications: first, to measure the impact of these classifications on the inventory management indicators, especially on the difference between the theoretical and measured service level. Subsequently, this analysis will enable us to suggest improvements to the classic inventory management procedure in order to establish a better definition of the service degree to be applied in the inventory management model in the case of spare parts based on the above rankings.

4.4 Application and Impact of Part Classifications on Inventory Management Performance

We use the same database used in Chapter 4, which consists of 36 months of demand history for 1500 spare part references. We use the profile classification of demand into three categories: stable, sporadic, and erratic, and that of the maturity level of parts into three categories: introduction, maturity, and end of life. We use a single inventory management policy based on continuous review and variable quantity forecasts (Si), we recall that this policy being continuous review and variable quantity is the most suitable for the case of spare parts inventory management. Also, we consider an order management mode with Backorders. See Figure 6.

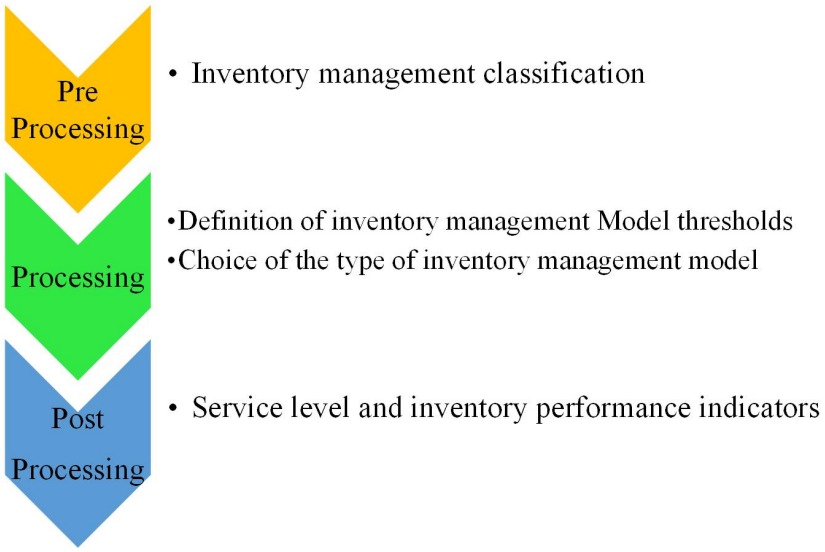

Figure 5. Overall stock Management Flow chart

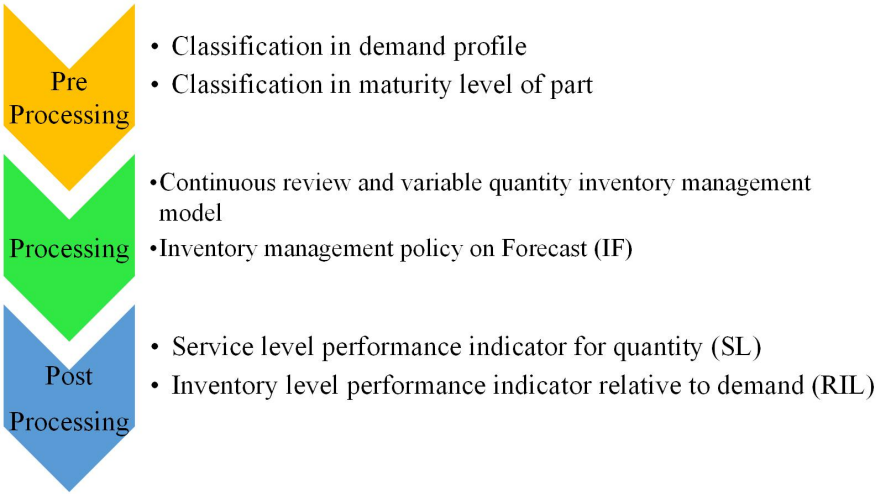

Figure 6. The experimented procedure of inventory management on forecasts

5. Data Analysis and Discussions

Here we represent the Data analysis and results of the experimental design described above by demand profile classification and then by part maturity level classification.

Results in-demand profile classification. See Figures 7-9.

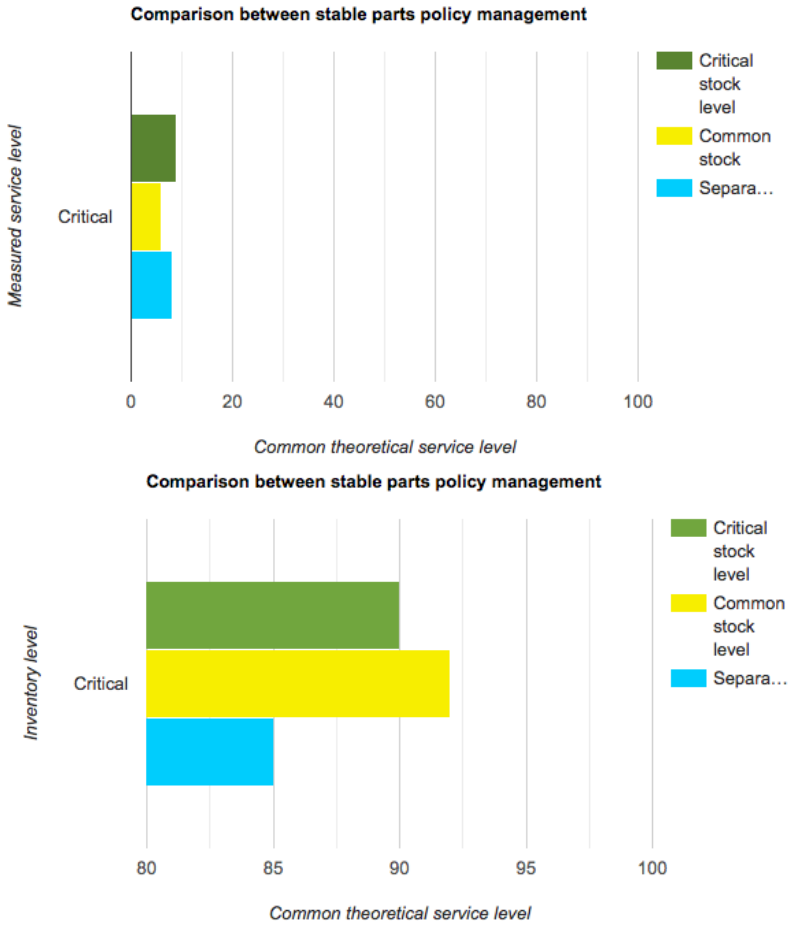

Figure 7. Comparison between policy management for stable parts

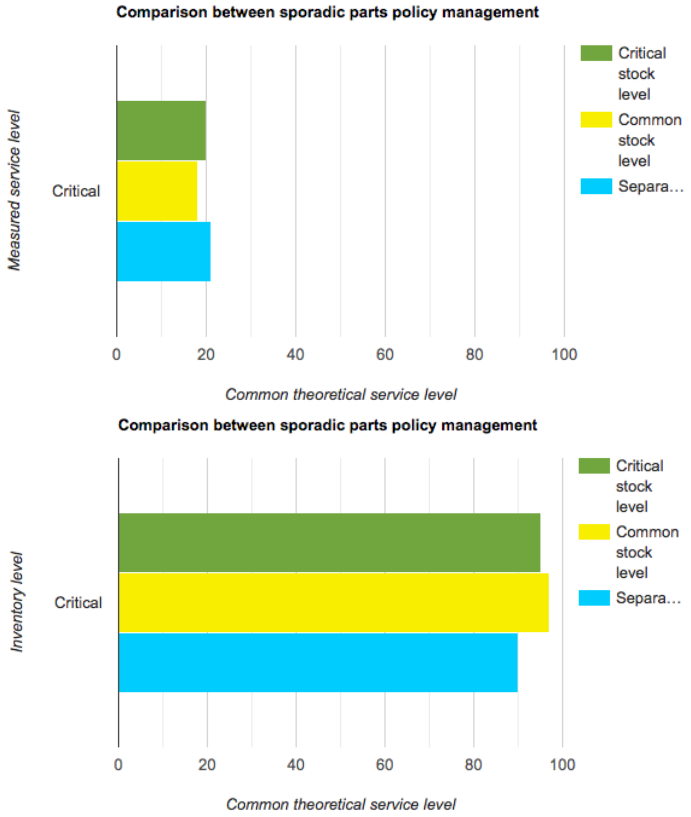

Figure 8. Comparison between policy management for sporadic parts

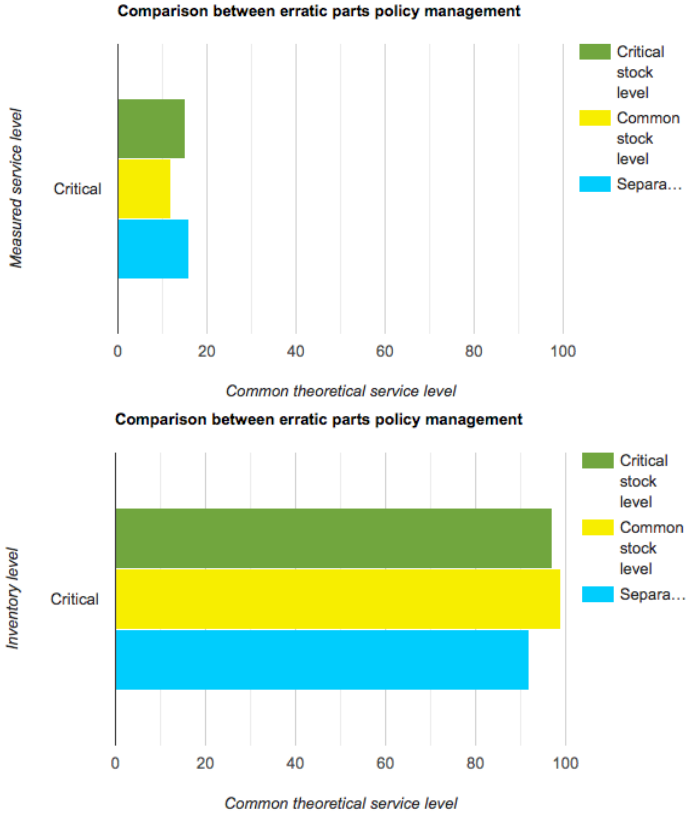

Figure 9. Comparison between policy management for erratic part

Discussion

This chapter confirmed the performance of the critical stock policy compared to the common stock policy and the separate stock policy from the point of view of the stock level regardless of the category of the part but highlights its limitation compared to other service level policies when dealing with sporadic demand.

Until there is a policy that outperforms the others for all classes of parts in terms of service and inventory performance, it is appropriate for decision-makers to first define their service or inventory priority for each class of parts, for instance by segmenting by unit cost, criticality, etc., and then choose, based on the demand ratio of each customer class and its required service level, demand profile, and degree of maturity, which policy to use for deciding on each class of spare parts.

In this work, we have addressed the problem of segmentation of forecasting and inventory management in the supply chain of spare parts at different service levels. The goal we set was to contribute to this issue in order to meet its objectives: improving service levels and optimizing inventories while considering certain specific characteristics of spare parts.

The management of the spare parts supply chain is both complicated and essential.

Complex, given the many flows in the chain, the demand profile, the risk of low turnover, inventory according to obsolescence, and the need to meet different service levels based on the priority of the maintenance contract and the prioritized parts.

It is essential because it enables the company to meet its commitments in terms of rapid maintenance interventions by improving the availability of parts and reducing transport and inventory costs by synchronizing flows and sharing stocks between maintenance technicians.

Forecasting and inventory management are key functions in this chain. Indeed, their production quality assures the best combination of service and inventory degrees. In this article, the reader is given a comprehensive overview of the instruments available in the literature in these processes, as well as a critical analysis of this work which raised the following main points:

- Segmentation: The absence of a consistent application of segmentation to both processes and the lack of use of segmentation into part life phases in model selection and performance evaluation.

- Performance assessment: The lack of a combination of forecasting method and inventory management model in performance assessment. In the absence of a combination of forecasting methods and inventory management models in the performance assessment, the selection of forecasting methods is restricted to statistical data.

- Customer Distinction: The absence of forecast-based inventory management models in the case of customer differentiation and a comparison with conventional policies based on spare parts segmentation.

6. Conclusions

Hybrid forecasting: hybrid methods have provided the opportunity to explore a combination of the characteristics of each method. Measures for evaluating the selection of forecasting methods were presented, enabling the use of information on lead time and the risk of over-or underestimating demand.

Inventory Management: Demand profile and part maturity level segmentations were included in this process to align with the forecasting process and to better determine the service level to be used in inventory management models.

In addition, approaches for evaluating forecasting methods based on inventory management criteria have been proposed to replace the classical statistical approach: by integrating the inventory management model in this selection, by considering service/inventory priorities based on part segmentation, and by using a multi-criteria decision support method.

Forecasting process and inventory management in the case of customer differentiation: The inventory rationing policy was adapted to the case of a forecast-based inventory management model and then compared to the separate stock and common stock policies based on demand profile segmentation and part maturity level.

This work was developed in parallel with an industrial application to the case of N.A.C.C. (North automobile components company). This company manages the supply and deployment of a very large number of spare parts references worldwide, for a large installed base of products and with a very high level of inventory, via a global and highly efficient supply chain. Therefore, the expertise of its inventory forecasting and procurement functions is essential to achieve its objectives. This work led to a complete revision of its industrial logic of inventory management by the implementation of a new segmentation of the parts considering the aspects of variability and intermittency of the demand, the construction of a decision-making logic of parameterization of the models used according to this new segmentation, the enrichment of the base of the methods used by the scientific methods of forecasting and the development of the approach of forecasting and inventory management presented in this article. This has resulted in significant improvements in service and

inventory levels and, more significantly, in bringing the industrial process in line with a scientific methodology that provides a basis for a set of future improvements.

Conflict of Interest

There is no conflict of interest.

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ARTICLE

What are Different Research Approaches? Comprehensive Review of Qualitative, Quantitative, and Mixed Method Research, Their Applications, Types, and Limitations

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ABSTRACT

There are different ways to examine and explain a study and its findings based on using numbers as a measure, a descriptive style, or a mixture of both. These three research approaches are quantitative, qualitative, and mixed methods that are commonly used by researchers in various research studies. However, with many options regarding the research design, it seems challenging for researchers to select the most appropriate approach based on the study and realize differences. This study provides a comprehensive review of qualitative, quantitative, and mixed-method research methods. Each method is clearly defined and specifically discussed based on applications, types, advantages, and limitations to help researchers identify select the most relevant type based on each study and navigate accordingly.

1. Research Approaches

Different types of research are classified based on a range of criteria including the application of study, the objectives of the research, and information sought [1]. These three main groups can be divided into sub-categories which are shown in Figure 1 [2]. However, there are also other types of categories that consider the time factor for the research. This method considers the data collection time and categorizes the research into historical, present, and futuristic types. The focus of this study is on different types of information sought from the research including qualitative and quantitative research approaches [1]. The most important differences between these two methods are:

- The degree of understanding and explanation of the phenomena as the aim of inquiry.
- The differences between impersonal and personal roles of the researchers.
- The differences between the constructed and discovered knowledge [3].

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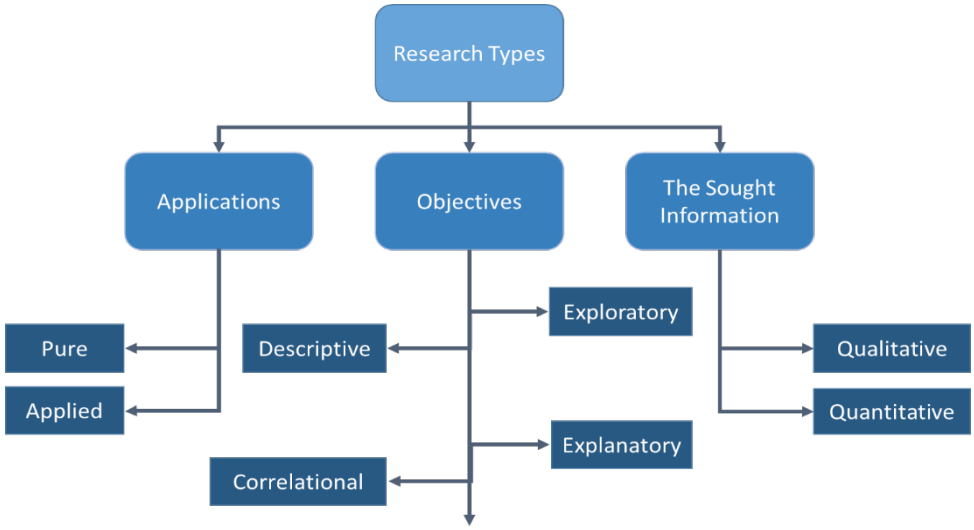

Figure 1. Types of Research [2]

The aim of this paper is to provide a comprehensive study considering the characteristics of each method, both advantages and limitations, and different types and approaches in the quantitative, qualitative, and mixed-method research. For this, the following sections are organized as:

Section 2 provides general descriptions on each of the research types. Section 3 is provided to discuss the qualitative approaches and the process. Section 4 includes the quantitative process and its different methods, and then the advantages and limitations of both methods are discussed in section 5. Finally, section 6 shows different types and important aspects of the mixed-method studies.

2. Qualitative, Quantitative, and Mixed Methods Definition

As it was discussed, research can be categorized into qualitative, quantitative approaches considering the type of data sought. Also, a mixture of these methods is known as mixed-method study that covers advantages of both methods. These approaches are defined as the following:

2.1 Qualitative Approach

There are different definitions for qualitative research. In general, these methods aim to address societies' scientific and practical issues and involve naturalistic and interpretative approaches to different subject matters. These methods utilize various empirical materials such as case studies, life experiences, and stories that show the routines and problems that individuals are struggling with in their lives through focusing on their in-depth meaning and motivations which cannot be defined by numbers. Qualitative research discusses two general criteria including [4]:

- The way to do things
- The outcome of tasks

Qualitative research aims to collect primary, first-hand, textual data and analyze it using specific interpretive methods. It is a useful method in studying a phenomenon with limited accessible information as its nature is exploratory. Thus, the qualitative approach can discover new insights, ideas, and generate new theories. It often concentrates on findings of the events in a particular context in a specific time without considering the consequences and results that may happen in the future or other contexts to generalize the results of the study [5].

2.2 Quantitative Approach

Quantitative research is the method of employing numerical values derived from observations to explain and describe the phenomena that the observations can reflect on them. This method employs both empirical statements, as descriptive statements about the meaning of the cases in real words not about the ought of the cases, and methods. It also applies the empirical evaluations intending to determine to which degree a norm or standard is fulfilled in a particular policy or program. Finally, the collected numerical data is analyzed using mathematical methods.

Besides, both qualitative and quantitative research approaches are designed to describe a topic; however, the last part of the definition is the difference which concentrates on different types of analysis methods which is mathematical using statistics in quantitative research. Gathering all these points together, quantitative research aims to define a particular phenomenon by collecting numerical data to address specific questions such as how many and what percentage in different fields including ed-

ucation, psychology, physics, biology, natural sciences, etc.

Furthermore, non-numerical information can also be collected in numerical forms using specifically designed instruments. These methods enable collecting quantitative data even from subjects which are about beliefs and attitudes. In other words, quantitative methods are the ways of determining social reality and employing specific questions to achieve numerical data for these specific purposes [2]. Different types of quantitative methods are discussed in the next section.

2.3 Mixed-method Approach

Mixed-method methods simply employ a combination of both qualitative and quantitative approaches based on the purpose of the study and the nature of the research question aiming to provide a better understanding of the subject. However, the focus can be on both methods equally or on one of the methods considering the selected integration process [5].

Utilizing the integration of both methods can help researchers to address complex research circumstances in different research fields such as social and health research. As these methods cover the advantages of both qualitative and quantitative methods, they can be useful in case that employing one of the approaches is not adequate in a study. Nowadays, in an interdisciplinary research atmosphere, a team of researchers with different methodological choices and interests can also benefit from utilizing mixed methods [6].

Nowadays, mixed methods are utilized in different fields and disciplines ranging from psychology to health and education as well. However, it is not required to necessarily be recognized as mixed-method and can be remained unknown. Therefore, researchers can promote the gained benefits of the applications of the mixed methods if they utilize them with a maximized extent to which they can employ these methods. The taxonomy of the possible designs is discussed in section 6.

3. Qualitative Research

This section provides a summary of qualitative research process and its different approaches. In qualitative data collection procedures, data should be gathered to respond project purpose, and also specific protocols and instruments should be conducted to record information. For address this purpose, you should first identify the sites, participants, documents, and required materials that can help to address under-study problems. Besides, a suitable sampling technique should be used as it is often not possible to collect data from the whole population [7]. Then, the type of data collection should be identified considering the merits and weaknesses that each type can bring to the research project. Data can be gathered through different data collection types such as observations, either semi-structured or unstructured, different materials and documents, conducting interviews, etc. Furthermore, you can also collect data from methods that go beyond the normal types such as examining a compendium of data types using factors during the interviews to evoke comments or utilizing a collection of sounds and tastes.

Next, an appropriate method should be used for recording the information. For example, observational protocols can include different formats such as one-page protocols including two sections known as descriptive and reflective notes. Descriptive notes include the information about dialogs reconstruction, individuals' portraits, the properties of the setting, etc. and the reflective section includes your personal thought as the researcher. The general components of these protocols include heading such as date, place, and identifications of both the participant and the interviewer, instructions, ice-breaker questions, detailed main questions, probes for the main questions and thank-you statements. In addition to the written notes, audio recording or videotaping methods can be utilized to record the information in this step.

Then, the results should be analyzed and interpreted. The main aim of the data analysis step is to make sense out of the gathered data [8]. For this, data should be initially prepared for analysis, then a suitable analysis method based on the chosen strategy for qualitative research should be employed and consequently an in-depth understanding of data should be achieved. By using different coding methods, themes and descriptions from data can be obtained. Then, the achieved themes or descriptions need to be interrelated and the real meanings of those themes or descriptions as the findings of the study should be represented and interpreted. However, other critical steps should be then considered to prove the validity (accuracy checking), reliability (achieving consistent results in comparison with other researchers or projects), and finally generalizability (utilizing the result for other people, places, etc.) of the research [6,9,10].

The following sub-sections focus on the qualitative methods more and provide different approaches to qualitative research method and its applications. The way to conduct research can overshadow the approach that should be applied during the study. The main methodological approaches that researchers can adopt during a qualitative study are listed in Figure 2.

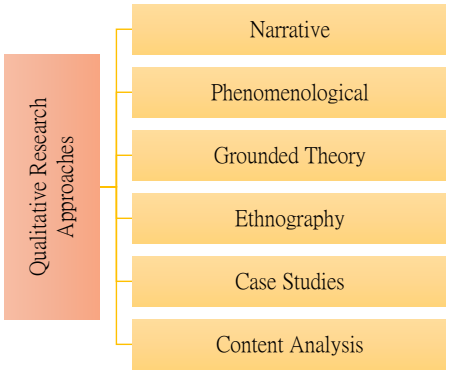

Figure 2. Qualitative Approaches

These types can be categorized based on the strategies of inquiry in the research. Each of these types addresses different demands in research. These demands can be from exploring activities and processes in the case studies and grounded theory approaches to extend the cultural-sharing attitudes of people or groups in ethnographic research approaches [11,12]. These strategies are discussed in the following:

3.1 Narrative

This strategy considers the narrative or stories of individuals about themselves or a series of events. The narrative strategy focuses on discovering the stories sequentially by emphasizing the characters [11]. It simply analyses people's lives based on their stories. People can explore two general questions about themselves:

- Who are they?
- How do their lives change over time?

Therefore, the life experiences are used as data in this inquiry type [5].

3.2 Phenomenological

This strategy employs individuals' viewpoints to perceive an experience and applies inward apprehension and consciousness as well as the outward appearance of the experiences by utilizing different tools such as memory, meaning, and image and emphasizes the consciousness intentionality. The phenomenological strategy aims to answer research questions using the individual's understanding of events by reliance on one to two hours of interview. These interviews that use an appropriate format of questions result in gaining the meaning of the events and experiences [12,13].

3.3 Grounded Theory

Obtaining abstract theories are the result of utilizing a grounded theory approach. These theories are derived from processes, participants' actions, and interactions which are stemmed from their viewpoint. The word grounded, in this approach, stems from the driven data which are collected from the research field not from the literature to develop theories [1]. These methods are used widely in social sciences to study the disciplines in sociology as they investigate both actions and interactions.

This method is also phenomenological and aims to understand the individuals' viewpoints regarding the experiences without considering that it is derived from a verifiable reality. However, this method goes beyond this description as uses these discoveries to develop theories. Therefore, it is mainly focused on emergence. That is to say, the study starts without any initial understanding and ends with the emergence of concepts from the collected data.

Methods of collecting data in this approach can be from on-site observations and interviews to historical reviews of tapes and records [12]. Literature reviews can be also a good contribution in addition to the other data collection methods [11]. Researchers use a set of standard formats including three coding processes (open, axial, and selective coding), and then develop their theories. In the final step, they explain five aspects in their reports as the following [12]:

- Research question description;
- Literature review;
- Methodology description;
- Explanation of the theory derived by the analysis of the data;
- A discussion about the implications.

3.4 Ethnography

Prolong observations are used in this approach to achieve the description and interpretation of the cultural-sharing groups. Ethnography considers both processes and products and instead of focusing on the way that data is gathered, wears the lens of data interpretation. Therefore, it recreates the behaviors, attitudes, knowledge, activities, etc. of a group of individuals to the readers. The main difference between case studies and narrative inquiries is focusing on the cultural parameters of the groups instead of single individuals [5]. This approach has anthropological backgrounds and different cultural parameters such as religious, geographical, social, etc. that can be considered in these approaches. There are different data collection methods that can be utilized in the ethnography approach as the following [11]:

- Interviews: Both formal and informal types are often conducted on different occasions;
- Observation: Both participant and non-participant types.

3.5 Case Studies

The main focus of case studies is to gain an in-depth exploration of about people, processes, events, and programs. This methodological approach can be applied in different fields ranging from political to medical research [1]. The structure of a case study stems from the issues, contexts, problems, and even the learning lessons from the events. These achieved patterns or lessons learned can be associated with specific theories. Researchers apply multiple data collection methods in this approach. For this purpose, the combination of direct observations, archival documents, artifacts, different visual or audio sources, and also interviews can be applied. However, it is important to regard the necessity of employing on-site collection methods which provide a direct interacting opportunity for researchers [12].

3.6 Content Analysis

In the body of materials, content analyses use a detailed examination of the contents systematically to gain patterns, biases, or themes. These materials are different forms of individuals' communications such as books, movies, newspapers, etc. [12,14]. It is also a suitable method for analyzing open-ended questions [11]. By reviewing these forms, researchers achieve specific characteristics from their content. This method is a high-objective approach encompassed a two-step data collection process:

- Putting the mentioned qualities in the specific frequency tables;
- Conducting statistical approaches to quantify the results [12].

Therefore, content analysis stems from quantitative methods, and it is mainly focused to gain frequency and counting patterns [11]. The report adopted from these approaches covers five main sections including material descriptions, under-study qualities, methodology description, frequency tables from statistical analysis, conclusion section which includes patterns, biases, and themes derived from the gathered data [12].

4. Quantitative Research

This section provides different quantitative research approaches as well as the methods of data collection and data analysis in this research method. The quantitative methods are designed to address rational questions which are shaped considering the variables of the study. The main aim is to achieve explanations and predictions which can be generalized to other people, events, and places. This process is initiated by stating the problem and involving the specific hypothesis according to the aim of the study. In the data collection procedure, instruments are used that are designed predetermined to gather quantitative data. There are different strategies to use in the data collection section such as conducting surveys and experimental methods [12]. The important point to consider is that the instruments need to be structured and validated to provide a precise measurement possibility to gain reliable quantitative data [15].

Then, the gathered data should be analyzed statistically using different quantitative analysis techniques such as descriptive analysis, explanatory analysis, and inferential types. The data analysis process, generally, aims to achieve statistical relationships between the variables [8]. Hypotheses and theories can be tested using the findings of the study. Consequently, findings of the research should be described and interpreted. The final reports are statistical, and they include the results significance and a comparison between the meanings [15]. More specifically, the common main steps for experimental methods include:

1) Identifying the participants and variables
2) Identifying the materials and instruments
3) Illustrating the design of the research using figures and appropriate notions

The steps of the process are followed by a validity step which aims to determine the validity of the constructs and statistics [10]. This process aims to identify possible threats to the validity which can be as the following:

- Internal validity threats stem from experimental processes, behaviors, or experiences of individuals that are able to threaten the establishment of correct inferences from gathered data.
- External validity threats can happen when the researcher finds inferences that are not correct from the sample data to other individuals, other situations, other places, etc., or simply generalizes beyond the participants of the experiment [10].

And in surveys, the main stages you need to consider are [6]:

1) Discuss main subjects such as the purpose of your study, population, sampling method and size, design survey instruments and their important items, correlations between variables, research questions, etc.
2) Analyzing data;
3) Interpreting results.

As discussed in the qualitative section, quantitative research can also be categorized into different approaches. Different strategies of qualitative research are listed in Figure 3. These approaches are described as the following:

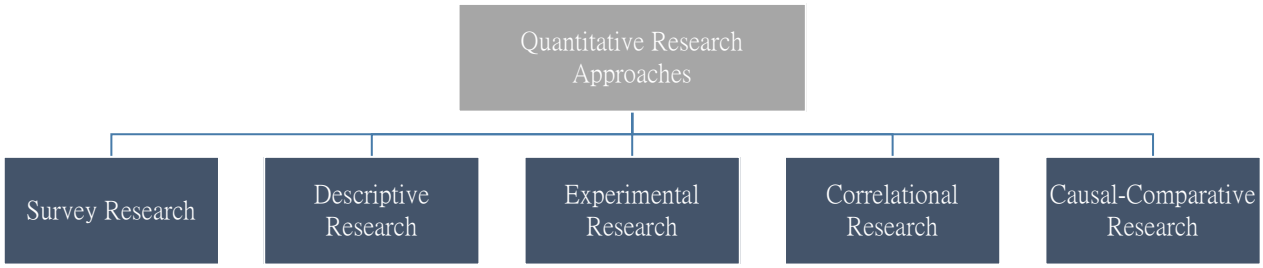

Figure 3. Quantitative Approaches

4.1 Survey Research

According to a dictionary named Merriam-Webster survey is derived from "surveer" (Angola-French Word) and means "to look over"; and it is the act of collecting data about a group or an area by questioning people [15]. This method is one of the most frequently used qualitative approaches [16]. This approach aims to measure the qualities of a specific target population considering a part of that population named sample by using a designed instruction recognized as a questionnaire and adopting statistical methods [7]. This method can study an individual's attitudes, beliefs, etc. using an appropriate sampling method. The data are gathered from the sample, and then the result is generalized to the target population [17]. Thus, this section of the population represents the beliefs, viewpoints, and opinions of the whole population. The most important aspects in surveys are gaining a suitable [2]:

- Sampling process;
- Questionnaire design;
- Administration of the questionnaire;
- Data analysis process.

4.2 Descriptive Research

This approach is a basic method to explain events and situations exactly during their current status. By providing systematic research about phenomena, it aims to either explore the correlation between the phenomena using observations or define their attitudes [12].

4.3 Experimental Research

The treatment of an intervention can be investigated through an experimental research approach to achieve the result of the treatment on the under-study group. These approaches include three types of designs:

- Pre-experimental design: a non-random selected control group or an independent variable that does not vary
- True experimental design: high control possibility on the system and highly valid results
- Quasi-experimental design: limited and low control, low validity, and not randomly selected samples [12,15].

4.4 Correlational Research

Correlational strategies as the exploratory methods aim to measure two general aspects regarding the relationships between two or more variables in the sample or the whole population [18,19]:

- Whether the connections exist or not;
- The degrees of the existent relationships.

A specific coefficient recognized as a correlation coefficient with values ranging from +1.00 to –1.00 is employed to determine and examine the extent of relationships. The values closer to the maximum and minimum have demonstrated relationships and strong correlations. The negative values show the inverse relationship between the variables as one goes up the other goes down [15].

4.5 Causal-comparative Research

This method examines the cause-effect relationships by determining how the independent variables can overshadow the dependent ones. Therefore, this helps researchers to discover the interaction of independent variables between themselves and their impact on dependent variables [12].

This method is also known as "Ex post facto" which means "from after the fact" as the researcher aims to study the problems using the variables which are in retrospect. The dependent variables are immediately observable, and the important point is to discover the antecedents that lead to the consequence. There are two types of casual-comparative approaches:

- First, retrospective type that concentrates to determine whether a variable has prejudiced another variable or not; and consider if the effects of the precise issue have already happened as a necessary point. This type is a commonly used technique.
- Second, the prospective type that researcher starts with causes to explore the effects of an issue [15].

5. Advantages and Limitations of Quantitative and Qualitative Research Methods

After providing information about the strategies of inquiry, data collection, and analysis in both methods, this section aims to discuss the merits and demerits of both techniques.

This can be specifically helpful in the next section to discover the requirement to employ mixed methods when these limits can overshadow the result of the study negatively and to define if the advantage of one method can save the research by employing an integrated method. Important advantages and disadvantages of different types of research are provided in Table 1.

Table 1. Advantages and Disadvantages of Qualitative and Quantitative Methods [9,12]

Type of Research	Advantages	Disadvantages
Qualitative	• The possibility of achieving in-detail and in-depth information regarding feelings, events, etc. • Obtaining the real meanings of the actions. • Discovering individuals' experiences in different situations historically. • Ideographic research. • The possibility of interacting with the participants during the data collection procedures. • Addressing complex issues due to the flexible structures and giving freedom to the participants.	• Lack of concentration on contextual sensitivities concentrated more on experiences and meanings. • Being based on phenomenological methods. • Low credibility is an important limit in some fields such as policy makers. • Findings are not generalizable since sample sizes are small. • Difficult interpretation and analysis processes. • Time-consuming data analysis processes.
Quantitative	• The possibility of generalizing results. • The findings represent the population due to the large sample sizes. • The possibility of sharing and replicating the documentation of methods and frameworks. • The possibility of replicating the study over time due to the standardized methods. • Being time efficient.	• Limits in providing hidden reasons in individuals' feelings, acts, etc. • Time-consuming sampling processes. • Facing limits of deep and in-detail explanation. • Failing to describe the way social realities are shaped. • Taking snapshots of phenomena and obtaining data using objective methods.

6. Mixed Method Research

The aim of employing mixed methods has been discussed before and main six types of mixed methods will be discussed in this section. However, the components of the mixed method procedures and four important aspects which are the basis of the shaping of integration processes will be explained. We also add a helpful checklist for the strategy of choosing a suitable mixed-method process. Finally, the data collection and analysis in these methods are discussed.

6.1 Important Aspects of the Mixed Method Research

Four important aspects of mixed methods are provided that are the basis of shaping different typologies in this research method. These important aspects are explained in Table 2.

6.2 Mixed Method Types

After discussing the important aspects of designing mixed-method studies, different types of mixed methods including six main categories are listed in Figure 4 as discussed in this section.

6.2.1 Sequential Design

Sequential Explanatory: Quantitative data are collected and analyzed in the first stage of this type. Then, in the second phase, the same processes are managed for qualitative data. The weighting on the quantitative data is more and the mixing process is based on the connection of both types of data but in the separated forms. It occurs when the results of quantitative as the initial type inform the data collection in the second type is qualitative. This method is employed when it is aimed to employ qualitative data as the follow-up for the initial quantitative results of method. This process is simply shown in Figure 5.

Sequential Exploratory: This strategy encompasses two different phases. The first phase involves qualitative data collection and analysis that is followed by quantitative data collection and analysis based on the result of the primary phase. In this case, weight is on the quantitative phase, and the mixing data are based on the connection of analysis of the first phase and the data collection of the second phase. The aim of this strategy is to use quantitative data to support the qualitative results' interpretation process. This method is shown in Figure 6.

Table 2. Aspects of Mixed Method Research [6]

Aspect	Types	Explanations
Timing	Time factor in data collection: 1. In different phases or sequentially 2. Gathered at the same time or concurrently	In the first type, either quantitative or qualitative data can be collected based on the initial intent. In case of collecting qualitative information first, exploring the subject using the participants in the setting would be the intent. In the second phase, the researcher's perception will be expanded based on a large sample. In the second type, the implementation is simultaneous. As it is more rational to collect both kinds of data at the same time in many research fields.
Weighting	1. Equal 2. Emphasizing the qualitative 3. Emphasizing the quantitative	This factor aims to define the priority given to the methods and is depends on three following factors: • Researcher's interests • Audiences including associations, faculty committees, etc. • The factor that the investigation aims to emphasize on it. For example, the priority is a deductive approach like testing a theory or an inductive one like generating a theme
Mixing	Stages of mixing are as the following: • Data collection • Data analysis • Interpretation of data • All together Mixing methods include: • Merging on one end of the continuum • Keeping separate on the other end of the continuum • Combing in a way between these two extremes. Mixing scenarios include: Connecting, Integrating, and Embedding More information.	The integration of data, research question, the philosophy of the research, and interpretation is considered, and two main factors are as the following: • When to mix? • How to mix? 1- Connecting both kinds of data during the phase including a mixing of the quantitative and qualitative methods that is connected between the data collection and data analysis in the first and second phases of the research; respectively. 2- Integrating or merging two databases by transforming qualitative ones to counts. 3- Using one of the secondary databases as the supporter for the primary one. Here, the secondary database is embedded into the larger study with a different type of data that is known as primary.
Theorizing	Guidance for the design of the mixed-method study.	Theories can be derived from: • Social sciences including leadership, attribution, and adoption theories • Broad theoretical lenses such as advocacy or participatory lens which considers race, gender, and class factors. Theories can be both explicit or implicit.

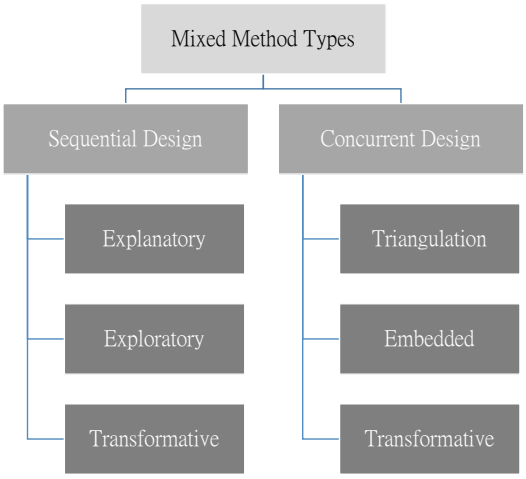

Figure 4. Mixed Method Types

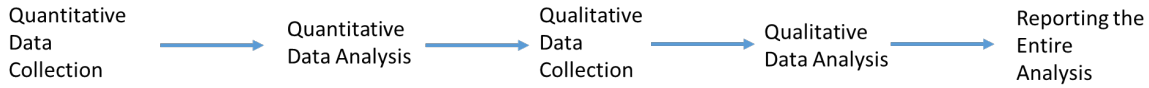

Figure 5. Sequential Explanatory Process

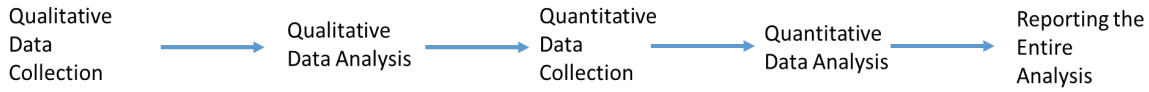

Figure 6. Sequential Exploratory Process

Sequential Transformative: It involves a two-phase process with a theoretical lens considering race, gender, and social sciences theories. The aim of the theoretical lens which is placed in the introduction section is to explore an issue. This problem can be in different fields such as social issues like injustice and inequality and the first phase can be qualitative or quantitative. The second phase which is based on the initial one can also be one of the two methods. The steps are shown in Figure 7. The weight can be given to quantitative and qualitative phases or equally can be distributed between both of them. Serving the theoretical perspective of the researcher in the best way is the purpose of employing this approach. Therefore, researchers are able to respond to the following points:

- Perceiving the changes in events and phenomena due to the studied results deeply;
- Giving a voice to different perspectives;
- Advocating for the participated individuals better.

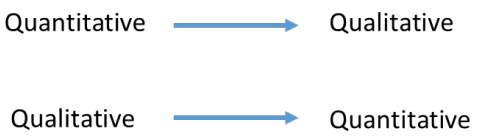

Figure 7. Sequential Transformative Process

6.2.2 Concurrent Design

Concurrent Triangulation: Data from qualitative and quantitative methods are gathered at one phase and concurrently. Next, the provided databases are examined to find differences, convergences, and possible combinations. The main aim of this method is either to cover the demerits of one of the single methods with the strengthening of the other one or to add the strengths of the methods to each other. Equal weighting is a priority in this type; however, sometimes the weight can be just given to one side. Finally, data is merged or integrated into the mixing process which happens commonly in the discussion or interpretation section as it is shown in Figure 8.

Concurrent Embedded: The main role of primary method in this case is to guide the project and the secondary one is the supportive database. The qualitative and quantitative data are gathered simultaneously during one phase for data collection and a theoretical perspective can be used to inform the first phase explicitly. The mixing process employs integration scenarios and then compares the data sources with each other. Researchers can benefit from this method in the following cases:

- The initial and secondary phases aim to address diverse questions;

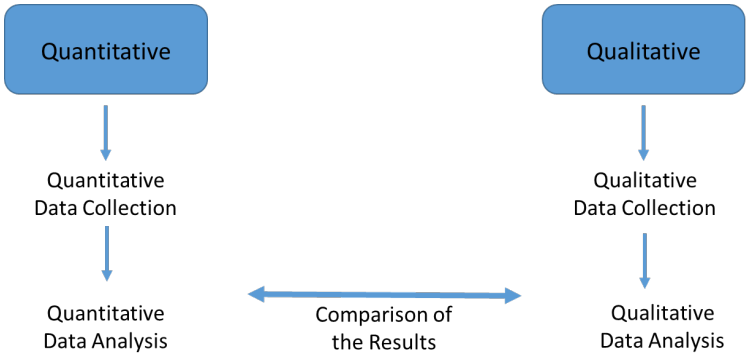

Figure 8. Concurrent Triangulation Process

- The phases aim to seek information from different analysis levels.

This method gives a broader perspective to the researcher due to employment of different methods instead of utilizing a single predominant one. Figure 9 demonstrates the method simply.

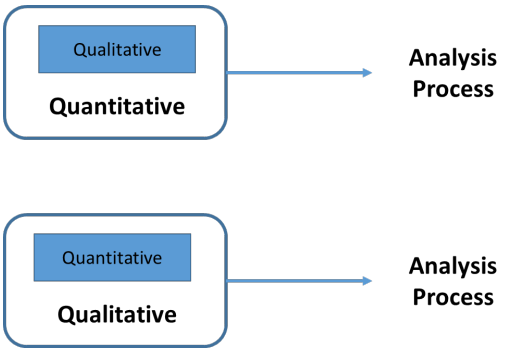

Figure 9. Concurrent Embedded Process

Concurrent Transformative: Both qualitative and quantitative methods are collected concurrently together using this method with a particular theoretical perspective. This perspective is based on ideologies and overshadows the aim and research questions of the project including different aspects of the methodology such as the chosen design, the identification of the data sources, interpretation and reporting processes, and analysis. Figure 10 shows the structure of this method.

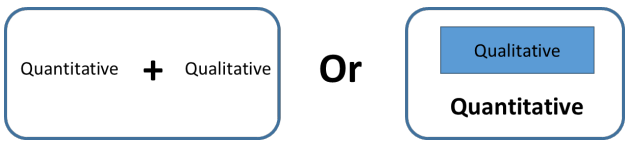

Figure 10. Concurrent Transformative Process

6.3 Tips for Choosing a Mixed Method

In the previous section, explanations for each of the types of mixed method were provided. In this section, some important tips are provided that help the researcher to choose the appropriate mixed method for the study as the following [6]:

- Consider the explanations provided in Table 2 and six approaches in mixed methods to gain a primary design.
- Estimate the available time for the data collection process considering concurrent processes are more time-consuming processes.
- Use embedded models in case the time factor is a limitation.
- Use an explanatory sequential model if there is limited experience in qualitative research and the required background in quantitative studies is substantial.
- Review published sources that are based on different methods in studies to determine the most appropriate approach.
- Finally, use an article using the same mixed method with your study as your advisor helping you to make your study feasible to other members such as audiences and committees [20].

7. Conclusions

A comprehensive review of the qualitative, quantitative, and mixed-method research methods is provided in this study. The methods and their applications are defined, and different approaches of quantitative and qualitative methods are reviewed together with a brief description of their process steps. Survey research, descriptive research, experimental research, correlational research, and causal-comparative research methods for quantitative studies are also reviewed. In terms of qualitative approaches, narrative, phenomenological, grounded theory, ethnography, case studies, content analysis were discussed. Then, the advantages and demerits of the qualitative and quantitative methods were compared. Consequently, the important aspects of mixing processes are provided, and six major strategies are described in this method. Finally, the points that need to be considered to choose an appropriate mixed method strategy are listed.

Conflict of Interest

There is no conflict of interest.

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ARTICLE

Comparative Analysis on Road Users' Cost Using HDM-4 Software and Manual Technique: A Case of Addis Ababa-Adama Expressway

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ABSTRACT

Continuous changes in vehicle technology, road condition, traffic compositions initiate the change or updating of road users' cost models. So that it needs to practice a continuous revision or update periodically for realistic estimation of costs and benefits. This paper presented the relationship and comparison between road users' cost along Addis Ababa-Adama newly constructed expressway using the Highway Development and Management (HDM-4) Software and manually using formulations developed in the Portuguese model. The method started with data collection. All input data were collected from primary and secondary sources. The primary data utilized an interview, and secondary data were sourced out from pertinent documents, both published and unpublished. More data were gathered that related to vehicles. The vehicles using the road are classified based on the manual from the Ethiopian Road Authority as cars, utilities, small bus, large bus, small truck, medium truck, heavy truck, and truck trailer. The collected data have been input into the HDM-4 interface; the output of the analysis was vehicle operating costs, travel time, and road users' cost as a summation. Using manual technique and HDM-4 Software, Birr 128.62/km/vehicle and Birr 139.23/km/vehicle, respectively, were found from road users' costs analysis. The result shows the difference of Birr 10.61. Also, the correlation coefficient of 0.75 is determined, which shows that the two results of road users' costs are highly related. As a result, the study reveals that the application of HDM-4 Software and the manual technique formulations from the Portuguese model can be adopted interchangeably to calculate Road Users' Cost of road sections in Ethiopia. Hence, the study results are expected to be an eye-opener for a future similar project by the concerned agencies.

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1. Introduction

Constructing and improving roads with recently found technologies is now experienced around the world. Improvements in a country's road network are intended to counterbalance the road users' cost, which indirectly results in savings for road users [1]. A study was conducted on-road user cost and savings in the UK [2]. As a result, it states that a road project should be assessed in terms of its primary effects, such as economic, social, financial, safety, and environmental effects. Among the above effects, economic analysis is a vital one that includes identifying, measuring, and comparing the social benefits and costs of an investment project or program [3]. Therefore, the economic analysis of road projects is conducted using different tools such as a highway development and management tool (HDM-4) and using different models developed in different countries. From these models developed, the Portuguese road user cost analysis model [4] is used for the calculation of the vehicle operating cost and travel time cost in this study. The models are presented in a way that they can implement using locally available data.

RUCs calculation includes the estimation of monetary and non-monetary effects. Based on the scope of the research, monetary impacts consist of main vehicle operating costs (VOCs) and the value of travel time considered as a cost (TTCs). As mentioned above, these fundamental components of road users' costs would be calculated separately using different parameters and input data [5]. However, the road users cost study is familiar to our country, this study was focused on the analysis of road users' cost (RUCs) in the case of Addis Ababa to Adama newly constructed expressway road, which is located in the south-eastern part of Ethiopia. This expressway selected for the case study is the first expressway in Ethiopia and East Africa. The route has an 83 km length and is a six-lane two-way road with a design speed of 100 km/hr-120 km/hr. The road officially opens for the public in September 2014GC.

To do the research, the following objectives of the study are: (1) To analyze Road Users' Costs using HDM-4 Software; (2) To apply the manual technique for the analysis of Road Users' Costs; (3) To compare the results of post-operational values of Road Users' Cost of both methods.

2. Materials and Methods

The methods started with data collection that includes road network data like (length, width, roughness, pavement type), traffic volume and composition, fuel, engine oil, tire, vehicle maintenance labor costs, crew costs, overhead costs, and interest rate. Data also include annual kilometers driven by vehicle type, hours driven per year by vehicle type, vehicle ages, percent of the time for private use and gross vehicle weight, and costs of working and non-working time. All input data were collected from primary and secondary sources. Then this collected data have been used for HDM-4 Software as an input to analyze the road users' cost. The same data were used to analyze road users' costs using formulations found from the Portuguese model manually. After inserting all required data, the program would run the analysis and generate the results. The expected outputs of the analysis are vehicle operating cost and travel time cost. These outputs were generated in monetary terms, and the results were then compared with both findings, one found from manual technique calculation and one from HDM-4.

2.1 Study Area

The Addis Ababa-Adama Road is selected as a study site since it is handling a heavy volume of traffic along the import-export corridor between the Port of Djibouti and the hinterland of Ethiopia resulting in significant economic and social importance. The length of the expressway is 83 km starting from UNISA Square (Akaki sub-city) to Adama town. This road is geographically located southeast of Addis Ababa and connects the major city of Addis Ababa and Adama thereby and bypasses other cities in between including Dukem, Bishoftu, and Modjo. The new road is 20 km shorter than the old Addis Adaba Adama road while the route is fenced on either side for protection from pedestrians and animals. The following Figure 1 shows the project location of the study area.

2.2 Study Design Process

The design process of the research is shown in the Figure 2 below.

2.3 Sampling Techniques and Sample Size

For this study, non-probability (purposive) sampling techniques were used. Purposive sampling is being used since these road users need to be identified and defined into groups or strata based on their characteristics. The non-probability (purposive sampling) has been used to get easy access to passengers and drivers who frequently use this toll road. And the sample size has been determined from the following formula [6].

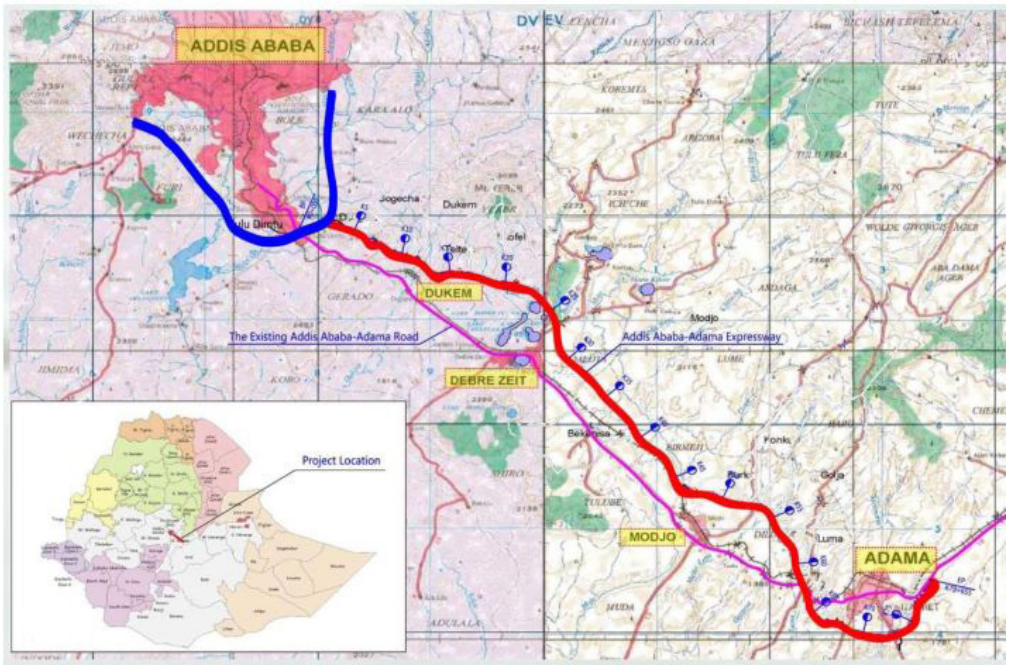

Figure 1. Project location of the study road

Source: Pavement report of Addis-Ababa toll motorway project

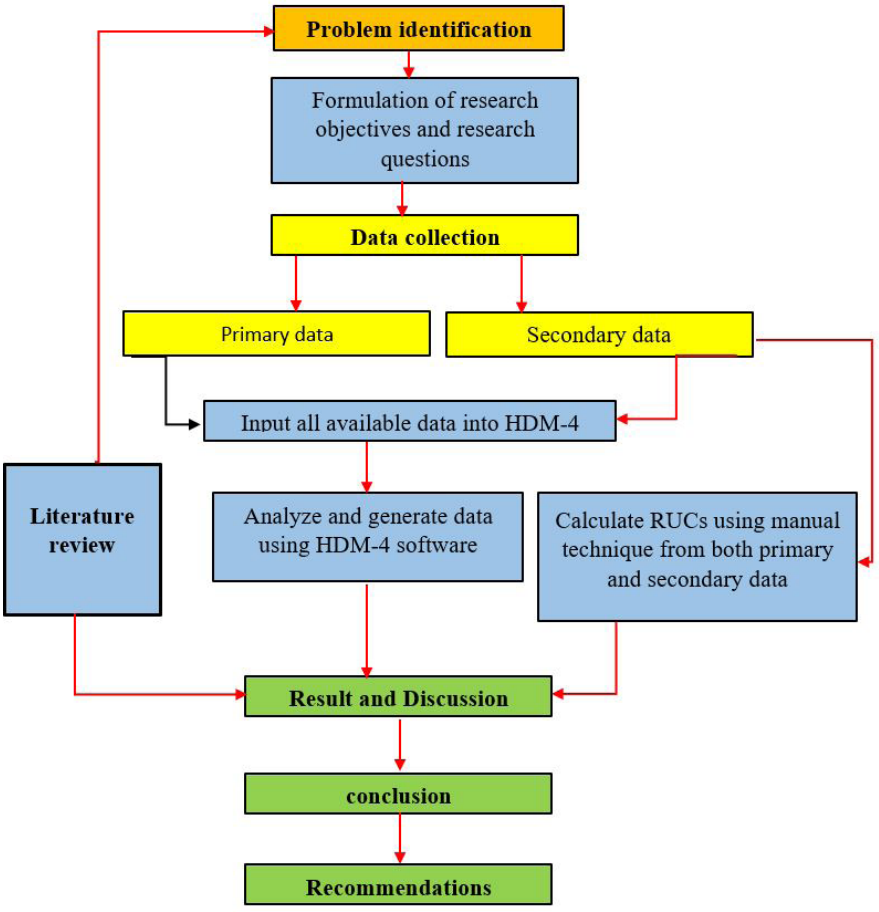

Figure 2. General structure of study methodology

$$n = \left[z^2 \times \frac{p \times q}{d^2} \right] \quad (1)$$

where:

n- sample size

z - linked to 95% confidence interval (use 1.96)

p – expected prevalence (as a fraction of 1.0)

q – 1-p (expected non-prevalence)

d – relative desired precision

Using p (0.5), q (1-0.5=0.5), d (10%), z (1.96), for the population of greater than 100,000 as recommended [6,7], then the sample size becomes 96.04 which is approximately taken as 100.

2.4 Data Requirements

Both methods, the HDM-4, and the manual technique need recently available and updated data to give more realistic results. The HDM-4 needs a wide range of data than the manual technique (formulas from the Portuguese model). The data used for the analysis of RUC by these methods include:

(i.) Road network data – The road network data include all necessary data available about the section under study. The section's functional condition and structural condition are gathered as input data. The data available from ERA (Ethiopian Road Authority), concerning the definition, pavement surface type, condition, and geometry of the section were collected.

(ii.) Vehicle fleet – According to the vehicle classification from the manual of Ethiopian road authority vehicles are classified into eight classes for the study.

(iii.) Cost data – Every vehicle using a road section has a cost associated with it. Vehicle operating costs and time costs for the passengers are significant. There are different components related to vehicle operating cost, i.e., fuel cost, lubricating oil cost, tire cost, maintenance cost, annual overhead cost, etc. And for the travel time cost, passenger working hour cost is also necessary. All this data required are gathered through an interview, from consulting office, government office, and from websites.

Data used for the analysis of the road users' cost, road network data, basic characteristics of the vehicle fleet, economic characteristics of vehicle fleet are presented in the following Table 1, Table 2 and Table 3 respectively.

Table 1. Road network data

Section ID	Section name	Road class	Surface class	Pavement type	Length (km)	Width (m)	No.of lanes	MT AADT	NMT AADT	AADT year
AAD	AA-D/Zeit	Primary or trunk	Bituminous	asphalt mix on granular base	33	12	6	9791	0	2015
DA	D/Zeit-Adama	Primary or trunk	Bituminous	asphalt mix on granular base	50	12	6	12817	0	2015

Table 2. Basic characteristics of the vehicle fleet

Vehicles	Base type	Tire type	Annual kilometer	Annual working hours	Average service life	Passenger occupancy	Initial composition	Growth rate
car	Medium Car	Bias-ply	20,000	2,400	10	1	9.0	23
utilities	Four Wheel Drive	Bias-ply	35,000	2,800	12	3	10.4	11
Small Bus	Light Bus	Bias-ply	40,000	2,800	12	15	17.9	13
Large Bus	Heavy Bus	Bias-ply	70,000	4,200	12	60	6.7	5
Small Truck	Light Truck	Bias-ply	50,000	2,800	15	0	11.2	17
Medium Truck	Medium Truck	Bias-ply	80,000	2,500	15	0	14.6	11
Heavy truck	Heavy Truck	Bias-ply	80,000	3,080	15	0	17.4	11
Truck and Trailer	Heavy Truck	Bias-ply	80,000	3,080	15	0	12.8	14

Table 3. Economic characteristics of the vehicle fleet

Vehicles	New vehicle price **	Tire price **	Fuel (per lit) **	Lubricating price (per lit) **	crew wage (per hr.)	Annual overhead	passenger working	passenger non-working
car	1,514,750	2,490	21.58	166.00	20.83	29,050	0	0
utilities	2,686,295	5,810	19.24	166.00	20.83	46,480	55.00	18.00
Small Bus	1,452,500	7,470	19.24	166.00	31.25	29,880	35.00	9.00
Large Bus	2,697,500	14,525	19.24	166.00	59.89	49,800	35.00	9.00
Small Truck	1,535,500	8,300	19.24	166.00	36.46	29,040	0.00	0.00
Medium Truck	2,241,000	10,790	19.24	166.00	46.87	41,500	0.00	0.00
Heavy truck	4,067,000	16,600	19.24	166.00	54.69	83,000	0.00	0.00
Truck and Trailer	3,901,000	14,940	19.24	166.00	54.69	74,700	0.00	0.00

*All costs are in Ethiopian Birr (ETB)

** Economic cost

2.5 Methods of Analysis

The HDM-4 Software and the formulas from the Portuguese RUC model are used for the analysis of road users' costs.

2.5.1 Highway Development and Management Tool (HDM-4)

Highway development and management tool is a computer-based software developed by the world bank for decision-making and checking the engineering and economic viability of road projects. This software is developed using various data from different countries around the world and is more practiced in developing countries to judge the economic feasibility of upcoming projects of roads. The new HDM-4 requires a wider range of data input when compared to HDM-III [8]. Running HDM-4 provides different outputs, including a report for traffic, deterioration/works effects, road user effects, environmental effects, cost streams, economic evaluation, and multi-criteria analysis [2]. Each report presents the effect of the proposed option. HDM-4 is used by a wider range of users (e.g., governments, consultants, and agencies) in both developed and developing countries. The software performs the following analysis based on engineering and economic aspects of the given project or program and the analysis can be addressed in three ways project analysis, program analysis, and strategy analysis [9].

A project-level pavement management analysis can be performed using the software's "project analysis" application module, which is a focal point of this study. Using the road user effects model of the software the results like vehicle operating cost, travel time cost, and road users' cost as a summation was determined.

2.5.2 Formulations from the Portuguese RUC Model

Simple formulations with the ability to calibrate and calculate road user cost components were developed in the Portuguese RUC model, and these formulations are adopted in this study for calculation of RUC besides the HDM-4 Software using locally available data gathered through an interview and from secondary sources.

3. Results and Discussion

The study covers the road users' cost analysis using both HDM-4 Software and the manual technique using basic formulas developed in the Portuguese RUC model. The same data collected is used for both methods, and a comparison of the results is made finally. The results of the analysis are expressed cost per kilometer of the section. The analysis is done for 6 years (i.e. 2015GC-2020GC). Since the road begins service on 2014GC and post-operational road user cost is needed to attain the period from the beginning of the operation to the year 2020GC is taken. The selected section of the Addis Ababa-Adama Expressway has an 83 km length, and for the matter of analysis, it is divided into two sections. The sections are Addis Ababa-D/Zeit which counts about 33 km in length and D/Zeit-Adama, which counts about 50 km in length. This section is chosen because it is the busiest section that connects the center to the main import-export corridor of Djibouti; it has a large traffic volume; the first expressway and data are available for the analysis. The total traffic in terms of AADT is collected from the annual

count conducted by the Ethiopian Road Authority (ERA), and the initial composition of vehicle classes is also expressed. The annual growth rate of each type of vehicle of the selected section is also specified. The maintenance and rehabilitation work costs for the past years were collected from the Ethiopian Toll Roads Enterprise (ETRE), which is a firm that manages the expressway. For the analysis using HDM-4 the discount rate of 10.26% is used as recommended by the Ethiopian road authority. After running the program vehicle operating cost, travel time cost, and summing both road users' cost is generated. These results are generated in the form of tables and figures.

3.1 HDM-4 Results

From the above input data, the software generates outputs for vehicle operating cost, travel time cost, and road users' cost as a summation of operating and travel time costs. As observed from the section Addis Ababa – Debirezeit analysis, the minimum value of vehicle operating cost was observed ETB 8.11/km/vehicle for small bus, and a higher value was observed ETB 29.43/km/vehicle for a truck trailer. This means for traversing a kilometre of the section, the vehicles expend 8.11 Birr and 29.43 Birr per kilometer, respectively, resulting from fuel, engine oil, tire consumption, maintenance, and crew cost.

The values estimated for travel time cost showed that the minimum value is observed for a car with the value of ETB 0.49/km/vehicle, and the higher value observed is for a large bus with a value of ETB 9.08/km/vehicle.

The result from the summation of both vehicles operating and travel time cost, which results for road users' cost, observed that the higher value was obtained for truck trailers with the value of ETB 29.47/km/vehicle. The minimum value was obtained ETB 9.14/km/vehicle for a small truck. The remaining vehicle's results for vehicle operating cost, travel time, and road users' cost as summation from the software are presented in the following Figure 3, Figure 4 and Figure 5 respectively.

Figure 3. Average vehicle operating cost per kilometer

Figure 4. Average travel time cost per kilometer

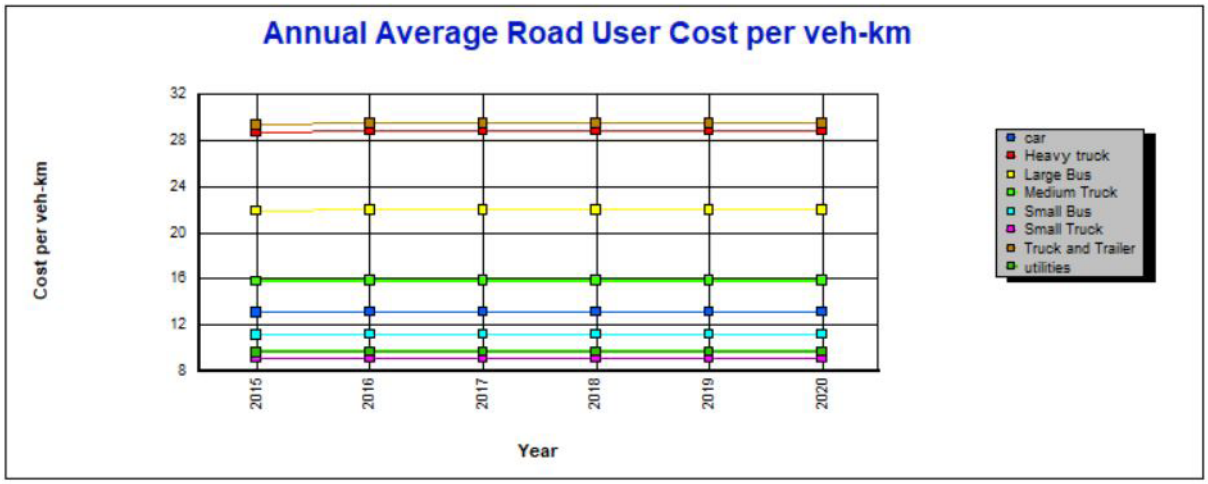

Figure 5. Average road users' cost per kilometer

The values generated from software for vehicle operating cost, travel time cost, and road users' cost respectively in the row as presented in the table below. The analysis is done for six years beginning from 2015GC to 2020GC and the values for all years are presented in the Table4 below.

Table 4. RUC output from HDM-4 Software

Year	Car	Utilities	Small Bus	Large Bus	Small Truck	Medium Truck	Heavy truck	Truck and Trailer	Total
2015	12.63	8.48	8.09	12.83	9.13	15.76	28.68	29.32	124.91
	0.49	1.17	3.09	9.07	0.00	0.01	0.02	0.02	13.87
	13.12	9.65	11.18	21.90	9.13	15.77	28.70	29.33	138.78
2016	12.64	8.49	8.12	12.89	9.16	15.81	28.81	29.45	125.36
	0.49	1.17	3.10	9.08	0.00	0.01	0.02	0.02	13.89
	13.14	9.67	11.22	21.97	9.16	15.82	28.82	29.46	139.26
2017	12.64	8.49	8.12	12.89	9.16	15.81	28.81	29.45	125.38
	0.49	1.17	3.10	9.08	0.00	0.01	0.02	0.02	13.89
	13.14	9.67	11.22	21.97	9.16	15.82	28.83	29.47	139.28
2018	12.64	8.49	8.12	12.89	9.16	15.81	28.81	29.45	125.39
	0.49	1.17	3.10	9.08	0.00	0.01	0.02	0.02	13.89
	13.14	9.67	11.22	21.97	9.16	15.82	28.83	29.47	139.28
2019	12.64	8.49	8.12	12.89	9.16	15.81	28.81	29.45	125.39
	0.49	1.17	3.10	9.08	0.00	0.01	0.02	0.02	13.89
	13.14	9.67	11.22	21.97	9.16	15.82	28.83	29.47	139.28
2020	12.64	8.49	8.12	12.89	9.16	15.81	28.81	29.45	125.39
	0.49	1.17	3.10	9.08	0.00	0.01	0.02	0.02	13.89
	13.14	9.67	11.22	21.97	9.16	15.82	28.83	29.47	139.28
Total	75.85	50.95	48.68	77.29	54.91	94.82	172.75	176.57	751.82
	2.97	7.03	18.60	54.46	0.03	0.06	0.09	0.09	83.34
	78.82	57.98	67.28	131.75	54.94	94.88	172.84	176.67	835.16

Note:

1st Row: Annual average Vehicle Operating Cost per vehicle kilometer.

2nd Row: Annual average Travel Time Cost per vehicle kilometer.

3rd Row: Annual average Road User Cost per vehicle kilometer

3.2 Manual Technique Results

These types of costs are generated by the users of the road themselves, depending on the facility the road provided them. Vehicle operating cost and travel time costs were considered main components of road user cost and were frequently determined. These two mentioned costs were analyzed in this study even though there is a growing interest in the accident, environmental, congestion, crash, and various other social costs that have been shown recently. The following equations are used [4].

$$RUC=VOC+VOT+AC \quad (2)$$

(i) Vehicle operating costs

Vehicle operating costs are travel costs that differ according to vehicle usage and based on vehicle kilometer traveled. Fuel consumption, engine oil consumption, tire consumption, vehicle maintenance, and repair cost, and vehicle depreciation costs that are based on the vehicle's use and service lifespan are all taken into account for assessing the value of vehicle operating cost.

$$VOC = AADT \times \sum_{i=1}^{n} (VOC_i \times P_i) \quad (3)$$

$$VOC_i = Cf_i + Ct_i + Cm_i + Cd_i + Cl_i \quad (4)$$

$$Cf_i = cf_i \times Cmf_i \quad (5)$$

$$Ct_i = \frac{nt_i \times Cmt_i}{tsl_i} \quad (6)$$

$$Cm_i = \frac{Cmmt_i}{vsl_i \times kma_i} \quad (7)$$

$$Cd_i = \frac{Cmdt_i}{vsl_i \times kma_i} \quad (8)$$

where:
VOC – total vehicle operating cost
AADT – average annual daily traffic
VOC_i – vehicle operating cost for vehicle type i
P_i – vehicle proportion of class i for the AADT considered
Cf_i – fuel cost for a vehicle i
Ct_i – tire cost
Cm_i – maintenance cost
Cd_i – depreciation cost
cfi – fuel consumption for vehicle i in (lit/km)
cmf_i – fuel market price (economic) in (Br/lit)
nt_i – number of tires for a vehicle i
cmt_i – tire market price (Br/pieces)
tsl_i – tire service life (km)
$cmmt_i$ – total maintenance market price for a vehicle i (birr)
vsl_i – the vehicle i service life in years
kma_i – average annual kilometrages (km/year)
$cmdt_i$ – the total vehicle i depreciation market price (minus tire) in birr

Here in the model, they do not consider the value for the lubricating engine oil. The value of these lubricant costs will be found as:
Cl_i = cli*cmli
where:
Cl_i – lubricant cost (Br/km)
cli – lubricant consumption for a vehicle i in (lit/km)
cmli – lubricant market price in (Br/lit)

(ii) Travel time cost

Travel time cost is a cost generated from the working hour loss of a passenger.

$$VOT = AADT \times \sum_{i=1}^{n} (VOT_i \times p_i) \quad (9)$$

$$VOT_i = \frac{1}{S_i} \times \sum_{m=1}^{2} (TC_m \times OR_{i,m}) \quad (10)$$

$$TC_{m=1} = NAW \quad (11)$$

$$TC_{m=2} = 0.25 \times NAW \quad (12)$$

where:
VOT – the value of time
VOT_i – the value of time for a vehicle i in Br/km/vehicle
s_i – the average operating speed for a vehicle i in km/h
m – corresponds to travel purpose (m=1 for travel in work time and m=2 for travel in non-working time)
TC_m – the time cost for travel purpose m in Br/h/occupant
$OR_{i,m}$ – the occupancy rate for vehicle i and travel purpose m in occupant/vehicle
NAW – the national average wage in Br/h/person.

(iii) Road user cost from manual technique

The results from vehicle operating cost, travel time cost, and road users' cost are discussed below using figures and tables. The values from vehicle operating cost and from a value of time (travel time cost) are added together to get the aggregated value of RUCs for both sections. The Table 5 below shows the total RUCs result from the manual calculation.

According to the analysis done using the manual technique and results summarized and presented in the table above, it is observed that a small car accounts for a small amount of vehicle operating cost ETB 10.28/km/vehicle. This means a small car has to spend 10.28 Birr to travel a kilometre. This expenditure is not forced or generated by external factors; instead, it is expected to be covered by the users and is generated by the users themselves. For the

value of time (travel time cost), small cars have accounted ETB 0.5/km/vehicle expenditure. This means per vehicle of passengers working hours lost counts for 0.5 Birr per kilometre and will be considered a loss by the road user per kilometre. Utilities, small buses, large buses, medium trucks, and truck trailers have accounted for ETB 13.18/km/vehicle, 13.45/km/vehicle, 14.12/km/vehicle, 11.645/km/vehicle, and 23.21/km/vehicle operating costs, respectively.

Moreover, for travel time cost utilities, small buses, large buses account ETB 1.16/km/vehicle, 2.65/km/vehicle, and 8.52/km/vehicle, respectively. Here since small trucks, medium trucks, heavy trucks, and truck trailers have no passengers trip related to work purpose, the value of travel time cost (value of time for travel) becomes zero. Vehicles types with a higher occupancy rate of passengers show higher values of VOTs.

As summarized to road users costs, small cars have the lowest expenditure (10.78 ETB/km/vehicle), and truck trailer accounts for the larger value of road users' cost with (23.21 ETB/km/vehicle). The results discussed above and the remaining results of other vehicles are shown in a summarized figure below.

The results discussed above, and the remaining results of other vehicles are shown in a summarized form in Figure 6, Figure 7 and Figure 8 below.

Table 5. Summarized RUC from manual technique of both sections

Vehicle type	VOCi (ETB/km)	VOTi (ETB/km/vehicle)	RUCi (ETB/km)
Cars	10.28	0.5	10.78
Utilities	13.18	1.16	14.34
Small Bus	13.45	2.65	16.10
Large Bus	14.12	8.52	22.64
Small Truck	11.78	0	11.78
Medium Truck	11.78	0	11.78
Heavy Truck	17.99	0	17.99
Truck & Trailor	23.21	0	23.21

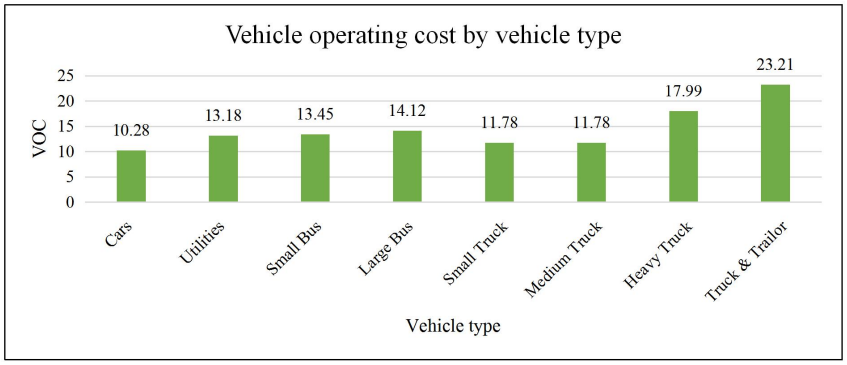

Figure 6. Average vehicle operating cost by vehicle type from manual calculation

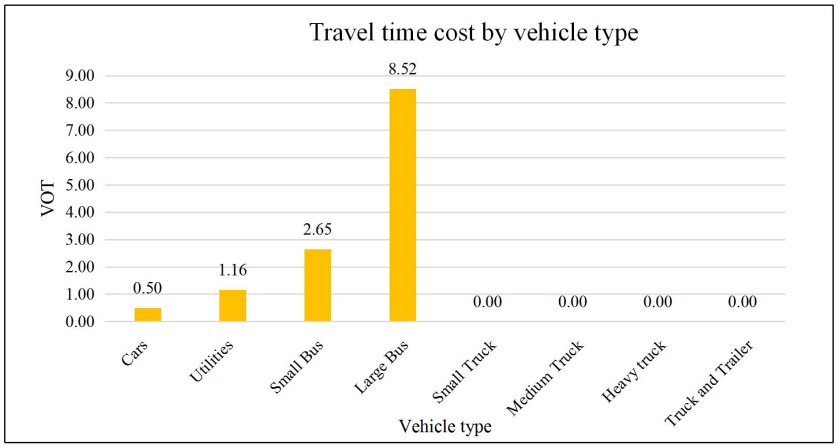

Figure 7. Average travel time cost by vehicle type from manual calculation

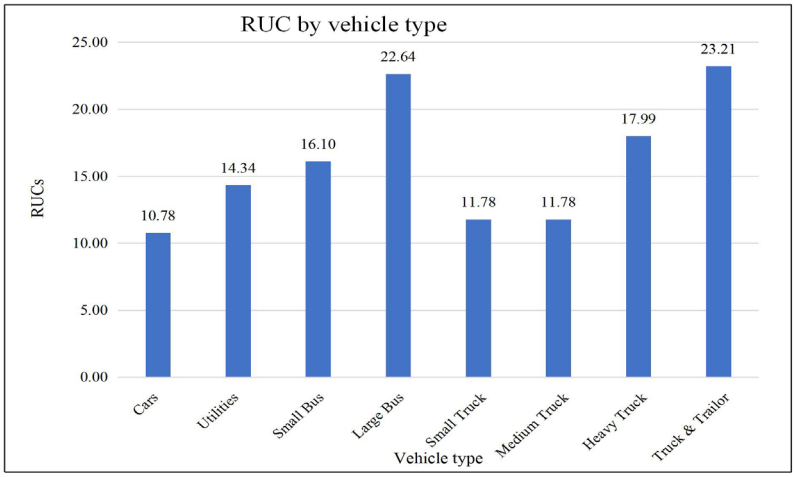

Figure 8. Summary of average RUC by vehicle type from manual calculation

3.3 Comparison of Results from Both Methods

The RUCs results of both methods are presented below. As a result, shows both methods give almost comparable results. A difference between a manually calculated total amount of road users' cost and that of HDM-4 Software result is Birr 10.6. HDM-4 uses more parameters and considers more factors to calculate vehicle operating cost and travel time cost. International roughness index (IRI) and average operating speed are the most concerns for the calculation of vehicle operating cost and more of traveling speed for travel time cost for the HDM-4. As shown in the resulting vehicle operating cost increases with an increasing amount of IRI and decreases with the increase in operating speed of the vehicle till optimum value, where there is an additional cost for fuel if the speed increases. Travel time is also affected by the operating speed, and this is well considered in the HDM-4. When the speed of the vehicle increases, the time is taken to complete the trip decreases, and the time value will increase, and when operating speed decreases, it shows vice versa. The manual technique has a simplified and adoptable equation the fluctuation of IRI and operating speed is not considered as that of appeared in the HDM-4. The manual technique is very easy and friendly for applying and estimating RUCs, and as shown in the table below, the results from this technique are more related to the HDM-4, which is accepted worldwide.

The results obtained from both methods were also checked using correlation coefficient, and the result found 0.75 which shows the two results are highly correlated. The output shown in the Table 6 reflects the correlation relation between the results.

Table 6. Correlation coefficient

	Manual	*HDM-4*
Manual	1	
HDM-4	0.75	1

Table 7. RUC comparison of both manual technique and HDM-4 Software methods

Vehicle type	**Manual calculation**			**HDM-4 calculation**			Ratio (HDM-4/manual)
	VOCi (ETB/km)	VOTi (ETB/km/vehicle)	RUCi (ETB/km)	VOCi (ETB/km)	VOTi (ETB/km/vehicle	RUCi (ETB/km)	
Cars	10.28	0.5	10.78	12.65	0.49	13.14	1.22
Utilities	13.18	1.16	14.34	8.5	1.17	9.67	0.67
Small Bus	13.45	2.65	16.1	8.12	3.1	11.22	0.70
Large Bus	14.12	8.52	22.64	12.89	9.08	21.97	0.97
Small Truck	11.78	0	11.78	9.16	0	9.16	0.78
Medium Truck	11.78	0	11.78	15.81	0	15.81	1.34
Heavy Truck	17.99	0	17.99	28.81	0	28.81	1.60
Truck & Trailor	23.21	0	23.21	29.45	0	29.45	1.27
Total	115.79	12.83	128.62	125.39	13.84	139.23	1.08

The results from both methods are presented in the Table 7 above. Also using the results presented, the results obtained from both methods can be easily correlated. As a result, the RUC of both methods has shown increasing and decreasing patterns vary according to the type of vehicle. This is also easily shown in Figure 9 below.

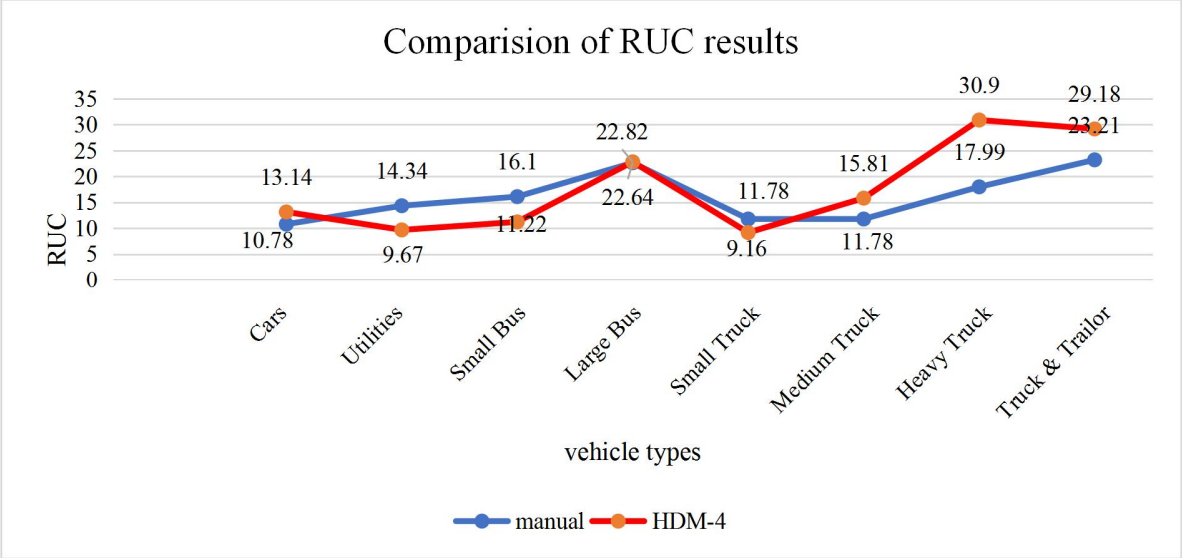

Figure 9. Summary on comparison of RUC of both methods

4. Conclusions

The results obtained from the analysis show minor variations. The VOC estimated using the manual technique and HDM-4 are ETB 115.79/km/vehicle and ETB 125.39/km/vehicle, respectively. On the other hand, the value of time (VOT) estimated are ETB 12.83/km/vehicle and ETB 13.84/km/vehicle, respectively. From the above results, the difference between the two methods becomes ETB 9.60/km/vehicle and ETB 1.01/km/vehicle, respectively. As a result, the RUC model provided by HDM-4 shows better estimates of VOC and VOT for each vehicle class than the manual technique used for analysis.

Generally, according to the findings explained above, one can use both methods or either of them.

- Where there is a lack of data, the manual technique may replace the HDM-4 since this software uses an extensive amount of data.
- From the results mentioned above, the HDM-4 model has estimated a larger value of costs for both VOC and VOT compared to the manual technique. So that for design and feasibility study purposes, the results from the HDM-4 Software can be used since it shows the larger value more concern will be given on the design part for providing a better quality of service for road users.
- It is advised that the fundamental parameters of the provided VOC and VOT valuation model be updated regularly by collecting current market pricing and that the model be thoroughly revised if the new volume is available.

Conflict of Interest

This is to declare that is no conflict of interests.

Findings

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