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Towards Sustainable Production Processes Reengineering: Case Study at INCOM Egypt

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Abstract: INCOM Egypt has undergone automation in some processes where critical aspects of its operations are transformed and automated. This paper presents an overview of INCOM Egypt processes using Ould Riva and analyses the process of 'handling a product'. It aims to demonstrate effective automation of the production of wires and cables process accompanied to Industry 4.0 while considering environmental and economic sustainability goals that were inhibited by COVID-19 restrictions. Ould's Riva method is used to analyse the production process of wires and cables to propose improvements for automating the process. Business process modelling is utilised to study the processes for clearer understating. The flow of information within the process is also analysed to integrate the production process with other processes and supply chains, which helps to identify which production activities can be automated and mainstreamed into the information flow to achieve environmental and economic sustainability. The context of INCOM Egypt, as a case study, is presented along with the Riva model of its operations. The paper identifies the before, i.e., As-Is process, and after, i.e., To-Be Process, automation of the 'handle a product' process using the Role Activity Diagram (RAD). The process involved redesigning and improving different activities to increase resource-use efficiency to participate in achieving the goals of sustainability. The focus of this paper is to investigate the negative impact of COVID-19 on sustainability and to examine the accomplishments of process automation of wire production towards environmental and economic sustainability. The results of the research reveal a relationship between business process modelling and sustainability. Moreover, automation of processes (Industry 4.0) is found to reduce the negative effect of COVID-19 on production. A triangulation between process modelling, process automation (Industry 4.0), and sustainability was determined. Each one is reinforcing and impacting one another. The RAD model demonstrates that automation of the activities in the process reduces waste, time, cost, and redundant processes as factors of sustainability, which may also help to lessen the unfavorable effects of the pandemic. The results proved generalisation on other organisations in the same line of business.

Keywords: process automation; Industry 4.0; environmental sustainability; process analysis; information flow; business process redesign; Riva; role activity diagram

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1. Introduction

Nowadays, complex businesses are most likely interrelated across various levels and departments of an organisation. Thus, suggested improvements and changes to a given function are likely to impact other processes. Many businesses tend to examine the key processes for technological and non-technological improvements, and subsequently consider the impact these changes can have on other organisational processes. However, the

COVID-19 pandemic necessitates immediate process replanning. In this regard, some organisations have already taken various initiatives in considering environmental sustainability as a major part of their proposed changes [1].

Automation has historically been used to help facilitate improvements that impact cost and/or quality, specifically with the introduction of Industry 4.0 which caused a dramatic change in production. It is also aligned with Sustainable Development Goals (SDGs, https://sdgs.un.org/goals/goal9 accessed on 1 January 2020), more specifically goal 9, i.e., build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation. To achieve process success, it is key to model the business operations, break down units of work of the organisation into business processes, and explore each process in terms of actions and interactions between processes and activities [2]. In addition to process automation, business process modelling is essential to transform the current business and increase its efficiency. This is mainly due to the ability to use business process modelling in analysing detailed business activities for process reengineering and developing a generalised workflow out of a set of specific business processes [3].

There exists a relationship between sustainability and manufacturing [4]. Current studies focused mainly on developed and developing countries, but none of them, to the best of our knowledge, included a case study from any African country. According to Bello et al. [1] manufacturing in African countries is characterised by high carbon emissions, resource duplication, and environmental degradation. This is also accompanied by high inventory, low workforce, and low operations capacity. It was also found that 63% of the companies included in the study showed the positive influence of sustainable operations on the overall performance of the company. Finally, there was a positive relationship between sustainability and economic, environmental, and social dimensions [4]. Moreover, Franciosi et al. [5] revealed that analysing business processes to meet social and technological challenges is essential to driving sustainable competitive advantages for current businesses. In addition, the strategic alignment of social and technological factors played a crucial role in making a competitive advantage sustainable. There is a clear gap in the literature regarding the ability to develop businesses that are better aligned with sustainability goals based on a thorough analysis of business process models. This study provides directions to incorporate informed sustainable strategies that will give businesses a competitive edge and allow them to prosper and perform better.

Ejsmont et al. [6] emphasise the relationship between sustainability and Industry 4.0, which reflects the ongoing effort to optimise current manufacturing processes sustainably. Nonetheless, researchers highlighted the need for further investigations to deal with the consequences of the continuously developing smart technologies which can cause additional environmental burdens. In addition, bridging the gap between expert knowledge, sustainability assessment methods, and the Industry 4.0 reference framework is a challenge. We claim that analysing business process models and architecture provides an authentic venue to bridge this gap.

To further investigate the impact of Industry 4.0 on the environmental sustainability in the production domain, analysts need to review production processes to understand their constituent activities and the information flow better. There is a variety of choices to model business processes, and researchers, over the last couple of decades, presented their views on the effectiveness of different modelling techniques. However, several models have stood the test of time by demonstrating their usability and ability to deliver strategic objectives for Information Technology project managers [7]. Thus, ref. [8] argues that system analysts should have a clear overview of the organisational architecture processes before individual processes are broken down for reengineering. Furthermore, identifying interlinked processes and the potential impact of any proposed changes remains a significant challenge and adds another layer of complexity. Hence, we claim that using Riva as a business process architecture modelling method provides valuable insights related to the business operations of a certain firm and at the same time captures an abstract view of business activities. Since the introduction of Riva in 2005, it has been remarkably used to successfully model many businesses around the world, including INCOM Egypt [9].

Due to the significance of the "handling of products" process in the organisation, as being the largest consumer of materials and the most expensive process in production [10], this paper has selected this process for analysis and automation using the Role Activity Diagram model (RAD). Furthermore, this paper attempts to demonstrate the benefits of combining the Riva method with RAD modelling in building a comprehensive view of the business process model for technological innovation in light of Industry 4.0 to achieve sustainability. More specifically, to (i) increase efficiency of resources utilisation as well as adopting advanced technologies and industrial processes, i.e., SDG 9—Target 9.4, and (ii) facilitate sustainable development in developing countries through enhanced technological and technical support to African countries, i.e., target 9.a. This research focuses on analysing the manufacturing process of wire manufacturing at INCOM Egypt company. This paper is organised as follows, first, the background of the company will be presented, followed by the effect of COVID-19 restrictions on the industry in Egypt. Second, illustrations about manufacturing companies and Industry 4.0 will be detailed to explore the latest advancements in production. Third, Ould's Riva method is explained as a technique for process modelling and analysis, and the importance of this technique will also be identified. Fourth, data collection methods and techniques are discussed, followed by modelling and analysis of the production processes. Finally, the findings of this paper are presented to emphasise the recommended changes and improvements in the process, which will impact environmental sustainability.

2. Background and Literature Review

Process modelling is key to attaining sustainability, according to [11], which focuses on enhancing sustainability in the production of bioplastics. Furthermore, other studies such as [12] were carried out to measure the relationship between process modelling and general business performance. This extends to the construction engineering industry as [13] studies structural sustainability based on the Building Information Modelling (BIM). Up to date, none of the previous studies focused on the business process in the industry of cables and wires production about sustainability, hence, this paper attempts to explore the production process of cables and wires by analysing the activities, information flow, and the roles of the process to investigate the activities that can be automated to achieve sustainability.

INCOM Egypt Company [14] is a subsidiary of INCOM Egypt America Inc. that was first established in 1994. It is a manufacturer of Custom Wire, Harness Assemblies, Flexible Building Cables, Power Supply Cords, and Plastic Spools. The company serves both the local and international markets. INCOM Egypt has several departments such as Sales, Research and Development, Production, Quality Control, Packing, Inventory Management, and Shipping, where each department has its own traditional and core processes. Production of wires and cables at INCOM Egypt is considered essential in the production process of other products such as power cord supplies, harness assemblies, and custom wire as a final product.

Considering the financial reports of INCOM Egypt in the past two years, the paper focuses on critical financial indices such as profitability, cost, and cash flow. After analysing the Balance Sheet of the company, from 2020 to 2021, it is evidenced that sales increased by 31%; cost of goods sold (COGS) increased by 30%; and, financial losses also increased by 11%. Whilst the increment in sales signifies positive improvements in market share and competitiveness, the parallel increment in COGS indicates that cost efficiency is deteriorating massively. Moreover, the increase in financial losses implies that the financial position of the company is unstable and progressing from bad to worse. In other words, whilst an increase in sales may be advantageous, it is vividly clear that INCOM Egypt is an exception to the general rule as it was unsuccessful in handling and controlling costs, which can be relied on inefficiency in cost management, and production processes, and waste of resources. INCOM Egypt faces many problems in production, e.g., machine breakdown, defective products, excessive use of materials, inaccurate information in and out of the process, delays in production, and others. From time to time, the company suffers financial losses due to the problems mentioned above. For instance, activities related to paperwork are carried out almost fully manually, except for inventory. Therefore, it can be observed that the quality of the information in the company is poor due to inaccuracy, delay, and impreciseness. In addition, the company suffers from the same problems in other processes such as purchasing, inventory management, quality control, shipping, and sales. It can be concluded that the improvement necessitates the usage of an ERP system. The inefficiency in processes at INCOM Egypt leads to various problems, which eventually create financial inconsistencies where financial results do not match among different departments leading to financial losses. The production process of wires and cables is selected for analysis as it contains a big part of manual activities that are done by labours. Labours need to enter information about production directly into the system otherwise automation of the production process can elimanate human intervention. In addition to, the negative impact of these anomalies and inefficient processes on profits and costs, COVID-19 increased the significance of deterioration, due to the restrictions imposed by the government. The paper considers the impact of COVID-19 on the Egyptian economy where the government is taking steps towards achieving sustainability. The paper then explores the advancements in the production process of wires and cables to reveal the interconnection between processes and improvements. The aim of improvements is to enhance the production process in the manner that reduces cost and increases profits. The following section discusses digital applications and technologies applied in production, introduced by Industry 4.0.

A section on process modelling and Ould's Riva method is presented to provide an understanding of the method used in the case analysis. The data collection method is discussed to support the analysis, and the following section presents background about INCOM Egypt, and the previously analysed hierarchal model is introduced, leading to the research questions, which are:

Research Question 1: How can the use of Ould's Riva modelling help identify efficiencies in the manufacturing processes of a semi-automated factory?

Research Question 2: What are the key processes in the production of wires and cables that can be adjusted to reduce waste and improve sustainability?

Research Question 3: How can process improvement and automation positively affect environmental and economic sustainability in the production of cables and wires post COVID-19 pandemic?

This is followed by the analysis of the 'Handle a product' process using RAD model to feature the activities that take place in the process, data flow, and roles in the process. The model is analysed to introduce the as-is and to-be for 'Handle a product' process. Finally, the conclusion discusses the triangulation between process modelling, technological advancements, and the impact of COVID-19 on production and how each one of them affects and reinforces the other.

2.1. COVID-19 and the Economy in Egypt

Like most countries in the world, COVID-19 negatively impacted the Egyptian economy, causing a decline in GDP growth due to the reduction in household consumption, as in 2019 its share was 82.9% of the total GDP [1]. This decline was caused by the government's decision to implement total and partial lockdown policies which involved shopping centers and restaurants to reduce the spread of COVID-19. Accordingly, the private sector, which is considered the second main contributor to GDP, with a growth of 17.7% was expected to fall due to uncertainty status [1]. With regards to employment, informal workers lost their jobs, which has consequently affected socio-economic development leading to a harsh recession. Though industrial components are being heavily traded, the supply chain was expected to suffer which negatively affect the trade of intermediate goods. Moreover, the effect of COVID-19 was expected to cause a global economic state of recession due to the major decline in international trade, which leads to a substantial decline in Egyptian exports.

The efficiency of energy sustainability in Egypt was low before 2016 compared to the worldwide due to subsidisation. This negatively affected the competitiveness of the Egyptian industry. Since 2016, the Egyptian government has introduced several measures to balance its finances, including the removal of subsidies on electricity and fuel, including natural gas, diesel, and oil. On the other hand, the Egyptian industry has started investing heavily in renewable energy to improve its energy efficiency, expecting it to achieve 42% by 2035 [15]. The direction of the Egyptian government is to improve environmental sustainability by improving industrial sustainability. Due to COVID-19, the government retracted on energy subsidies removal which led to a reduction of electricity and natural gas prices for the manufacturers of Steel, Aluminum, Copper, and Ceramic. This decision caused the implementation of renewable energy projects to slow down after the pandemic [15]. The effect of COVID-19 [16] led to an increase of poverty in different countries due to quarantines. While also, COVID-19 negatively impacted social capital as it plays a vital role in collaborative innovation, collective intelligence, and organisation sustainability [17].

According to [18], in their policy response to COVID-19 concerning Africa, it was claimed that facing the pandemic requires consideration of technological, trade, and industrial solutions. The research highlights the importance of supplying medical devices, drugs, and skilled personnel efficiently and effectively, which includes testing, protecting, treating, and curing. The complexity in deploying such requirements in timely, affordable, and safe conditions projects the significance of adopting automation of business processes. Hence, the use of the latest technologies provided in Industry 4.0 supports the application of social distancing while maintaining strict accuracy in the implementation of operations.

Ref. [19] highlighted the importance of professionalism and knowledge development of human capital including employees and stakeholders that could be achieved by providing constructive training. The essence of human capital lies in making some sort of decisions that necessitate being present at their workplace, which could be unsafe or prohibited under the pandemic's circumstances in different jurisdictions. Accordingly, it is an essential component for businesses post-COVID to enhance the awareness of technology usage, information accuracy, and automated decision making to cope with the new shift under the conditions of social distancing and work from home. The importance of technology training lies in its impact on the technological awareness of employees, as automation and technology have become dominant in many fields of business while also supporting sustainability in some aspects.

2.2. Production Process in Manufacturing Companies

There is an increased need to have more business models that can accommodate smart factories, whereby the models are able to interconnect machines with data processing in the traditional business sense [20] Specifically, modern factories are equipped with complex, distributed, multi-factor within a socio-production system that requires closer integration between business processes and production processes [21].

Like complex organisations, manufacturing companies have their own challenges, such as performance evaluation, business process improvements, product improvements, to mention but a few. Manufacturing companies rely considerably on the reliability and effectiveness of the business process to achieve their goals. For instance, ref. [22] investigated the impact of knowledge management on process and product innovation and operational performance for 207 manufacturing companies. The study indicated that process innovation was found to have a significant impact on operational performance. Also, process innovation plays a key mediating role between knowledge management and operational performance. Moreover, ref. [21] reveals the centric role of process understanding in devising an effective implementation of lean strategies in manufacturing organisations.

In addition, adopting process concepts and practices proved to be effective regardless of the domain of the production company, i.e., domain-independent [20]. For instance, ref. [23] investigated how combining total quality management and business process reengineering can improve drug manufacturing processes besides the studies mentioned above.

Another finding from [24] is that process improvement failure is not only due to poor execution or executive commitments, but it is also mainly due to neglecting the interdependences between processes from one side and strategy, people, and operations from the other side. This triggers the adoption of business process modelling for a better understanding of the processes and improvements by Industry 4.0 technological advancements to reduce cost, enhance quality, increase profit, and reduce waste while complying with environmental sustainability [25]. It has been demonstrated by [26] that organisational learning and corporate governance are vital to firms' sustainability. Moreover, leadership styles significantly enhance organisational learning but have no influence on a firm's sustainability. The relationship between organisational capabilities, corporate governance, leadership style, and sustainability is considerably enhanced by organisational learning. It also plays an important role in sustainability. Additionally, innovative culture moderates the relationship between firm sustainability and organisational learning [27]. By understanding the importance of learning in organisations, technological advancements could play a major role as part of the learning process to automate processes and thus discover the importance of sustainability. While leadership cannot control the firm's sustainability and innovative culture can help in organisational learning, therefore, this research studies the areas of improvement in the production process of wires and cables manufacturing company to achieve automation, hence, to achieve sustainability.

2.3. Technology Advancements in Manufacturing

The rapid development of disruptive technology has a dramatic effect on businesses, especially on manufacturing. That was mainly driven by a dynamic business environment and changes in customers' needs that are vital to manufacturing requiring more information to be available via smart factory—information flows between people, machines, and sensors [28]. Such innovation provides real-time visibility across the supply chain. Industry 4.0 initiatives enabled by cyber-physical Systems (CPSs), the Internet of Things (IoT) and Cloud Computing, ref. [29] lead to monitoring business processes by embedding smart products into physical processes [30]. European companies [31] with high profitability and turnover consider workers' training in 4.0 technologies, while also, exploiting more investments in technology. Accordingly, utilisation of technological capabilities [32] is essential to leverage the digital capabilities of a firm resulting in a better performance. Adopting a growth mindset will help us better grasp an organically creative attitude, resulting in more desirable outcomes. Furthermore, the growth mentality promotes creative activities and future creative accomplishments that impact technology [33]. To ensure success of technological advancements, controlling management in the presence of mature process is needed to enforce innovation activities and technological level of the company [34].

As recommended by [1], assessment of raw materials is required to consider local market substitutes or other sourcing countries. Accordingly, this will avoid a shortage in the supply chain. On this basis, the manufacturing sector in Egypt plays a major role to supply needed materials that are essential for production in the B2B market; for instance, INCOM Egypt for wire manufacturing is one of them.

In addition to the negative implications of COVID-19 on the economies in general, particularly in Egypt. Digital applications of Industry 4.0 are found to provide opportunities for disrupting manufacturing in Egypt. Therefore, the following are explanations of involved technologies in Industry 4.0 [1]:

Industrial Internet of Things (IIOT): because of COVID-19, social distancing increased the demand for IoT in Egypt, as there is more need for actuators and sensors to communicate and function electronically throughout the production processes with people. Augmented Reality (AR): AR has a great impact on manufacturing, specifically in the field of maintenance and the field of operations. It is also well-utilized in training/learning, remote assistance, inspection, and product design. The use of Computer-Aided Manufacturing, Virtual Reality, Augmented Reality, and Extended Reality in manufacturing [26,35]. 3D Printing: Also referred to as Additive Manufacturing, the use of 3D printing and additive manufacturing without human intervention leads to reduced material waste. It uses geometrical representations to create physical objects produced layer by layer by successive addition of materials. It is used for mass customisation in agriculture, the automotive industry, the locomotive industry, the aviation industry, and healthcare [36]. E-Commerce: it facilitates communication between manufacturers and their vendors and customers, especially under the highly imposed restrictions due to lockdown. Big Data Analytics: where complex analytical algorithms can be used to analyse large datasets to gain more understating of the market movements and better planning to achieve customer needs supported by data analytics [37]. Cloud Computing: no matter where employees are located, cloud computing allows the availability of information and systems to be accessed remotely. Digitised Supply Chain: provides integration between manufacturers, suppliers, and customers and thus more transparency among the supply chain to track the product through its manufacturing stages.

In this context, our research focuses on analysing the activities of 'Handle a product' process that might lead to elimination, modification, or insertion of activities to fit in automation.

2.4. Measuring and Controlling Sustainability

Sustainability definition comes from biology. For a process to be sustainable, it requires consumption at a pace that does not cause depletion of that resource. In an environmental context, the aim is to considers preserving resources for future generations while avoiding contaminants that could cause ecological harm [38]. United Nations (1987c) provides a comparable definition that focuses on the future generations to secure their resources needs. Education of sustainability in business schools and centers needs to be genuine, interrelating technical, cultural, and political fit that integrates legitimacy, resources, and collaboration. Putting sustainability into action and applying measurements are embedded in training and education. Therefore, a harmonical combination in strategies is essential for achieving sustainability [39]. Meanwhile [40] smart production along with sustainable supply chain are driven by recycling and reuse strategy for the circular economy to be achieved.

Attention must be directed towards economic development that has a direct impact on human and material capital. The presence of environmental regulations imposed by the government enhances air pollution and thus improves economic development while declining economic growth that intensifies air pollution [41].

SDAG was evidently successful in being embedded in policies, education and training, project planning, and publicly spreading at the local level. On the contrary, sustainability initiatives shall only be noticeable if their results proliferate and span the world on the global level [42].

Homogeneity of production processes and their activities from one side and sustainability from the other side is crucial to verify energy efficiency and minimisation. Sustainability assessment requires the presence of performance standards in production processes [43]. The study stresses addressing energy-related sustainability indicators of processes that affect sustainability. While automation of production processes guarantees precise data measurements while achieving integration of production systems involving social, economic, and environmental sustainability. As a matter of fact, CO_2 can be reduced based on the level of population size, however, the level of civilisation can have an opposite effect [44]. Profit-making firms are obstructed by ethics [45], moreover, total revenues that shareholders are trying to maximise are hampered by corporate sustainability performance [46].

The work by [47] uses ANN technology to develop a predictive model of sustainability measures that improve the quantity and quality of production. They developed a model based on artificial intelligence that delivers an accurate and efficient forecast, indicating that the constructed model has a high level of accuracy in predicting sustainable measures.

One key challenge, among others, in the criteria of sustainability lies in the uncertainty to accomplish those criteria, which also affects the prosperity of the market and achieving sustainability. Transparency and monitoring of sustainability criteria are proposed to control the functionality of the production at all stages of the production chain. The process of controlling sustainability criteria and measuring any progress towards achieving them is complicated and challenging to maintain; however, one technique to achieve it is to request involved parties to report their obligations while keeping independent auditing [4,48].

The work by [49] points out that natural resources as one important factor for sustainability are required imposition over suppliers to minimise the consumption of natural resources by improving efficiency and thus save the environmental risk.

According to [50], the following is a list of core indicators for sustainable products and their sustainable production:

1. Conservation of energy and materials and applying them for the most relevant result.
2. Reduction and elimination of wastes and ecologically incompatible by-products and recycled chemical substances, physical agents, technologies, and work practices that cause threats to the natural environment and human health.
3. The role of management is essential in controlling the economic performance by constantly evaluating and improving its effectiveness in the long term.
4. Safety of products and their packaging accompanied by their services is crucial throughout their lifecycle. They all need to be ecologically rigorous.

Industry 4.0 can reduce the environmental impact of a product, a process, or a service based on footprint data availability and traceable analysis. Therefore, working on business model innovation and efficiency in production can be investigated to examine the impact of technological advancement utilisation in the industry on sustainability. Hence it might contribute to sustainability to develop digital sustainable operations allowing to meet SDGs goals [51].

Worldwide, there are various sustainability measures and tracker dashboards such as SDG tracker and SDG Hub. Yet, they are not sufficient and still require further investigation.

2.5. Process Modelling

Naturally, a manufacturing environment would have information-based processing for a variety of tasks involving planning, procuring, ordering, managing logistics, and other processes. To model the business processes, Riva already provides the key modelling constructs. This paper, however, explores how the processes of a manufacturing domain, which includes control of auxiliary flows, can be analysed through Riva for improvement. Thus, this paper aims to demonstrate the possibility of improvements in manufacturing, whether it is automated or unautomated. Riva can be used to detail the manufacturing processes for better understanding, which can then provide a road map for improvements. This paper uses the term manufacturing processes in the same context as [28] present it as a "... transformation activity in which employees use the machine, energy, and information to transform the material into products". This process may also include modelling the business's movement within the factory as they transform the supply chain process. One challenge when modelling manufacturing processes is to model manual activities.

In the case of BPMN, an extension was needed to model these steps. Some of the added notations are manufacturing tasks, and resource containers with subtypes including machines, parts, and auxiliary material [44]. In addition, several gateways were proposed, including material route, the material selected, material split, and material joining. And this is not the only approach, as several other researchers have attempted to extend BPMN to reflect its flexibility in the modelling business and manufacturing operations [21,30,52,53].

Because of the large complexity of the operations at INCOM Egypt, this paper adopts the Business Process Architecture (BPA) as a supportive tool to analyse the Business Process (B.P.) of the company. BPA is used to refer to a systemised overview of Business Processes (B.P.) that specifies their relations, which can be accompanied by guidelines that determine how these processes must be organised [7]. BPA captures the abstract structure of business processes of a specific organisation and their relationships [2,54].

In this research, Ould's Riva method [55] is selected for the analysis of INCOM Egypt as it has several departments, each of which is responsible for carrying out critical tasks or activities in the organisation. With the understanding of those activities and their interconnections, the Business Process model can be attained. Several modelling methods to visualise patterns in business, and the modelling method shall provide a detailed level of understanding of the processes and their implementation. Due to the complexity of today's businesses, having an abstraction of their business model is necessary to comprehend the interaction between business processes. Out of this abstraction, one can visualise patterns within the organisation's value-added process that greatly affects environmental sustainability and its improvement.

One advantage of process modelling is breaking down the hierarchical level of business activities into detailed actions and interactions out of which one can analyse and improve the process, e.g., [55]. With the support of business process management software, processes in a model can be enacted to become real processes in the organisation. Ould's Riva method will be used in this research to capture the business process architecture, supported by the Role Activity Diagramming (RAD) for the 'Handle a Product' process in INCOM Egypt.

2.6. Methodology (Riva Method)

Literature evidence, e.g., ref. [2,7], shows that large organisations are increasingly adopting business process architecture due to its ability to unlock new business opportunities successfully. However, developing a sufficiently enough BPA is challenging for various reasons, including the domain of application and the purpose of the model. For instance, adopting an entity-centric modelling approach is different from the activity-centric modelling approach. The former focuses on what is being processed by the business, i.e., business entities, while the latter focuses on how business processes operate [56,57].

Business entities, according to [56,57], are a critical component of every business process architecture diagram. Riva's entity-centric approach [56,57] is thus one of its primary assets. The Riva technique for process modelling developed by [56,57] is business-oriented rather than software-oriented, focusing on the management of business entities through the actions and interactions of various roles rather than a reduction of business to logic. It was chosen as the most appropriate process modelling tool for the current study, which aims to delve further into the business of ports, for a variety of reasons:

- it looks to understand and design business processes rather than software * It concentrates on discovering that essential components of a business are not found in the detail of information or workflows
- it puts roles, actions, and interactions at the center of its detailed analysis rather than data items or process logic
- it provides a high-level, architectural way of examining business processes while complementing the lower-level analysis.
- it presents a well-developed notation, but one which can be manually and informally applied.

The Riva approach is a useful technique for performing thorough process analysis and implementing adjustments based on the findings. It does not begin with a commitment to existing work practices and technology platforms but rather aims to comprehend them in terms of what the business is truly about and what it is attempting to accomplish [2]. Using the approach in manufacturing allows focusing the analysis on the activities where it can make changes. A thorough examination of such areas may discover duplicate activities and departments inside an organisation that might be eliminated. While also improvements could be implemented in the short-term for trial- based on a short period that can be united to serve strategic goals [9].

Modelers must first identify their Essential Business Entities (EBEs); some of these EBEs will [56,57] have a lifespan, thus they will be labelled as Units of Work (UoW). Each organisation's procedures will be categorised into one of the following categories: Case Process (CP), Case Management Process (CMP), or Case Strategy Process (CSP) are all examples of case processes (CSP). It is possible to have designed business entities that aren't required. They still exist because of how a company organises its operations, such as forming business entities that lead to the specified unit of work. The Riva method may portray unnecessary activities, which might contribute to inefficiency or repetitive operations. As a result, it has the potential to pave the way for process improvement.

Riva's technique combines process architecture diagramming and role activity diagramming, which are two different types of diagrams. A process architecture diagram depicts some or all an organisation's business processes, as well as how they interact. A Role Activity Diagram depicts the activities inside roles and their relationships for a single process. To introduce the case procedure of 'Handle a product', the writers used a previously analysed architectural model that took place on INCOM Egypt. The authors utilised RAD to analyse this case process, detailing the activities of the process and illustrating information flow between the involved roles.

Ould adapted an earlier notation called RAD to represent the internal structure of a process in terms of roles, actions, and interactions.

A role is a set of actions that a person performs (or a group; or a machine). Within a process, roles interact with one another. In the notation, a role is represented by a large, rounded box within which actions are drawn. In the process, small black boxes connected by vertical lines represent actions. The lines represent the role's states as it moves from one action to the next.

Special notations are used to depict conditional and parallel paths through various areas of a role's activities. Interaction between two or more roles is represented by horizontal lines connecting white boxes within the roles. A stripe can be drawn on the box at the beginning of the interaction. The trigger symbol records an external event that causes a state change.

Riva process models serve as a foundation for process analysis and improvement. Process enhancements can be incremental or radical. Incremental improvements are more likely at the detailed process level (RAD), whereas radical improvements are more likely at the higher architectural level.

2.7. Data Collection

This section presents descriptions of the business processes of INCOM Egypt, based on the interviews conducted with the Chief Executive Officer, production department, planning department, sales department, inventory department, and quality control department at the factory of wires and cables. The researcher was granted access to these departments so that the research could be carried out.

In this research, interviews, observation, and analysis of documents were the main three methods of data collection. Data collection took place between 2019–2021, during the pandemic and post-pandemic re-opening. Key persons in wire production were interviewed for the research upon consent from the owner of the company.

The main function of the production department is to receive customer orders and production plans, request materials from the warehouse, start production according to the plans, and follow quality control instructions after inspection. These activities are complex compared to other activities due to quality standards, customer satisfaction, and safety requirements. To understand what the production process looks like, open interviews were conducted as a generous method to gather information about the case study. Researchers can talk to key interviewees and hear more about how the production works and the challenges they face in addition to more details outside the scope of the questions. Access to the facility also enables us to collect relevant supplemental documents and extend the interview data. The goal of the information series is to collect facts for the advent of manner models, one for the contemporary manufacturing manner and one for the manufacturing manner after proposed improvements. Several interviews were conducted in the departments surveyed. Interviews were first conducted in the production department followed by other relevant departments to integrate the activities of the process. The interview was only partially structured, and more questions were raised as the interview progresses. The purpose was to discover detailed business activities in the production process. At the beginning of the interview, general questions were asked to learn about the process, followed by different lines depending on the answers. Additional data about the activities in the production process was collected from the documents provided by the interviewees like sales order, work order, inventory records, and QC report. The process was also observed by the head researcher of this paper by attending the production process. One order was tracked from the time it arrived at the sales department followed by the planning department, production department, materials handling, and QC inspection. The next section provides a schedule of interviews in the departments mentioned above and a list of questions asked during the interview.

It was noticed that data collected from employees and labourers indicates poor quality of data, including the flow of data, the accuracy of data, timely data, and preciseness of data. One challenge in data collection was in the time needed to organise it and relate it to the process.

Table 1 shows the interviews that were conducted for the production department at INCOM Egypt, listed in number order by date.

Table 1. List of interviews for the Production Department at INCOM Egypt.

Number	Date	Interviewee
1	23 September 2020	Chief Executive Officer
2	24 September 2020	Head of Production Department
3	1 October 2020	Head of Planning Department
4	20 October 2020	Head of Sales Department
5	5 November 2020	Head of Quality Control Department
6	15 November 2020	Head of Inventory Department

Table 2 lists the interview questions in numerical order and links to the interviews at which they were asked. The questions ask about the workflow in a production environment, including the relevant departments of the process. Several questions are used to clarify the flow of information between departments. Other questions identify the activities of the departments that are interrelated and influential. A general prompt for use between departments has been created to provide a framework for the nature of the business within a department in terms of the activities and processes that each department performs, as well as describes the department's activities and responsibilities, and the participating role in processing orders and products.

Table 2. Interviews questions for the Production Department at INCOM Egypt.

Question Number	Question	Interview Number
1	What is the nature of the company's business?	1
2	Which sectors does the company serve?	1
3	What organisation size does the company serve?	1
4	Is the company working towards sustainability development?	1
5	What are the planned or follow-up steps required to make this development?	1
6	Does the company face any challenges/limitations while working on this achievement?	1
7	Explain the process of receiving materials from inventory after PP is received.	2

Table 2. *Cont.*

Question Number	Question	Interview Number
8	Explain the activities and responsibilities of the production department to fulfil an order.	2
9	Explain the activities and responsibilities of the Planning Department and the role of the department in producing the production plan?	3
10	How do you receive the sales order?	4
11	What happens to the sales order after it is received?	4
12	How is the quality control department informed to inspect semi-finished/finished products?	5
13	Explain the procedure of handling the QC report to related departments.	5
14	Explain the procedures of updating inventory levels.	6
15	Mention any information systems used to exchange data and information among departments.	2, 3, 4, 5, 6
16	Are there any plans towards achieving sustainability?	2, 3, 4, 5, 6

2.8. Process Modelling of INCOM Egypt

Figure 1 shows the Business Process Architecture Diagram (PAD) for INCOM Egypt [57]. The diagram shows actions and interactions between the organisation's processes analysed to present the initiation and delivery of information between processes. Referring to INCOM Egypt's PAD, the 'Handle a product' process is selected for analysis using RAD. While INCOM Egypt has more than one type of product, the production of cables and wires is selected for analysis. This model has been developed based on the Unit of Work (UOW) diagram [55]. Each unit of work was carefully selected and assessed to prove it is essential to the business; hence they are called Essential Business Entities (EBEs). The assessment is done according to the organization's perspective, organisations in the same line of business require the same processes to operate.

According to [57], INCOM Egypt lacks technological advancements in its processes that have incurred losses and suffered delays in production and delivery. This research examines the degree of automation in the 'Handle a product' process, whether it could be fully automated, semi-automated, or unautomated, to conclude sustainability readiness at INCOM Egypt as a production-related case in Egypt. The produced Riva diagram and all other supportive artifacts, including the RAD for the 'Handle a Product' process, will be further analysed to decide whether improvements are needed and what improvements look to be possible, mainly for automation. The ideal aim is to produce a sufficiently detailed model that a software system can support to serve as a base for information flow and Industry 4.0 related technologies enacting the improved process in the organisation.

Ould's Riva model has traditionally been used for I.T.-related system analysis and design. Despite an extensive review of the literature, the team could not find any case study linked to the use of Riva process modelling for manufacturing or production processes. Thus, this paper closes the literature gap in the potential use of the model beyond its original design.

To assess the impact of improvement introduced by the Riva Model, the authors will conduct a reflective analysis to identify the impact on processes, conveyance, security, and any reduction in inaccuracies and expenditures. The outcome should demonstrate an overall enhanced consideration of quality assurance of the given process. Thus, allowing the paper to establish if, in fact, the use of the model is suitable for improving environmental sustainability in production.

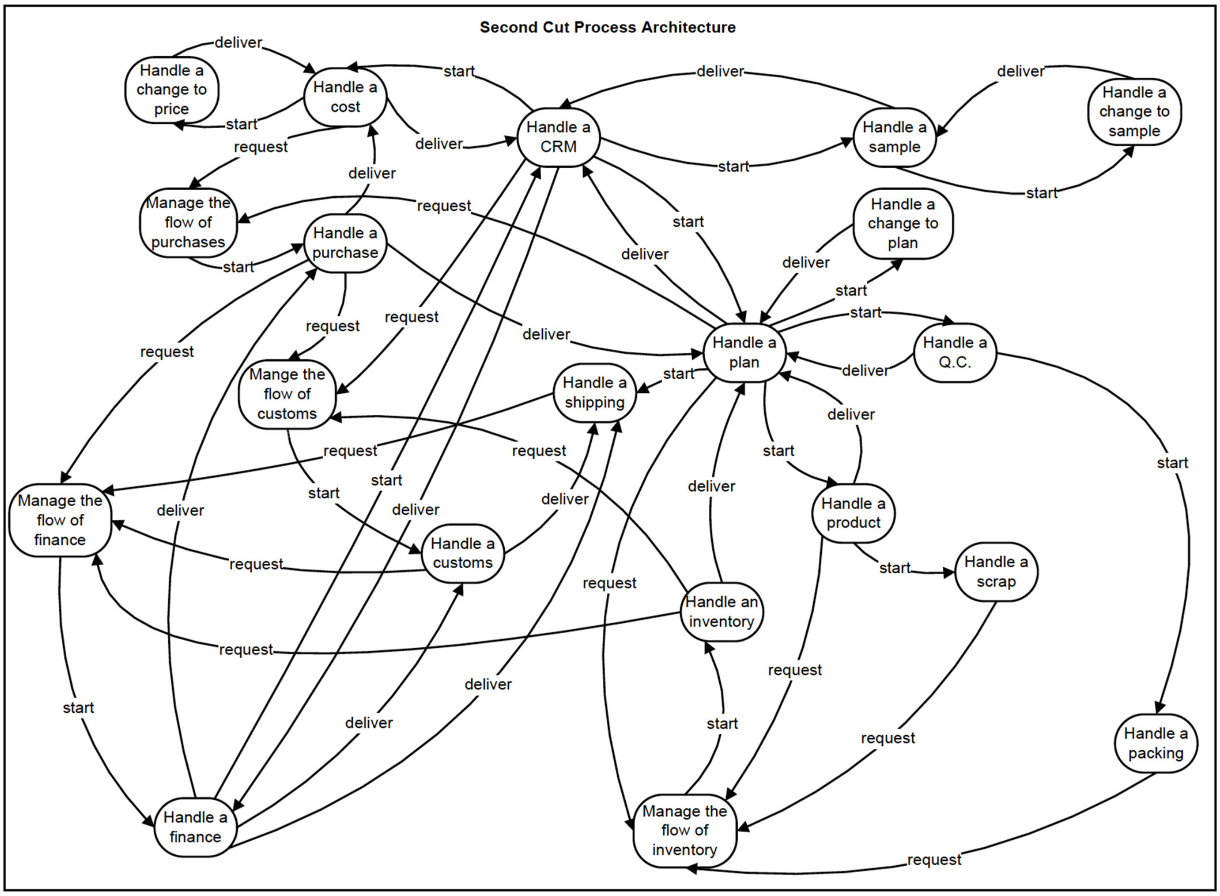

Figure 1. Business Process Architecture Diagram for INCOM Egypt. Reprinted with permission from ref. [56]. Copyright 2012 Copyright Rasha F. Ismail.

3. Results

This section describes the workflow and information flow of the business processes at INCOM Egypt based on a previous study done at the hierarchical level of the company. The 'handle a product' process will be detailed using RAD for a better understanding of the process and to examine possible improvements. As-is and to-be models are created and investigated in relation to the latest technologies supported by Industry 4.0., the study took place during the pandemic and post-pandemic period as well it takes into consideration the impact of change on sustainability.

3.1. Process Modelling of INCOM Egypt

The investigation of INCOM Egypt's current processes of 'handle a product' found limited automation of activities, involving planning, production, and inventory. Figure 2 shows Modelling' Handle a product' process at INCOM Egypt.

The 'Handle a Product' Process starts by receiving an order from a customer by email/fax to be sent to the planning department by email or on paper. The planning department prepares the production plan manually or by using excel in accordance with the inventory department. In 'Handle a Product' process, the production department receives the Product Plans (P.P.) and the order number on paper from the planning. Based on the plan, the production department requests materials for production from inventory by presenting the P.P. received from planning, who had also informed inventory about the required materials. The Inventory department reviews the quantities required and prepares them for the production department. Finally, information about the released quantities is recorded in excel files.

When the production process starts its operations, the materials pass from one stage of production to another. The semi-finished product is recorded in inventory records manually until the last stage of production is reached. Once the final product is produced, the production department requests verbally from the Quality Control (Q.C.) to inspect the finished product. After the Q.C. inspection takes place, a written report is sent to the production that indicates whether the product is ready for packing and shipping. Where defects are detected, a notice is issued with instructions to be fixed. Also, scrap is calculated and reported for quality assurance reasons such that defective products are also treated as scrap and added to the scrap number.

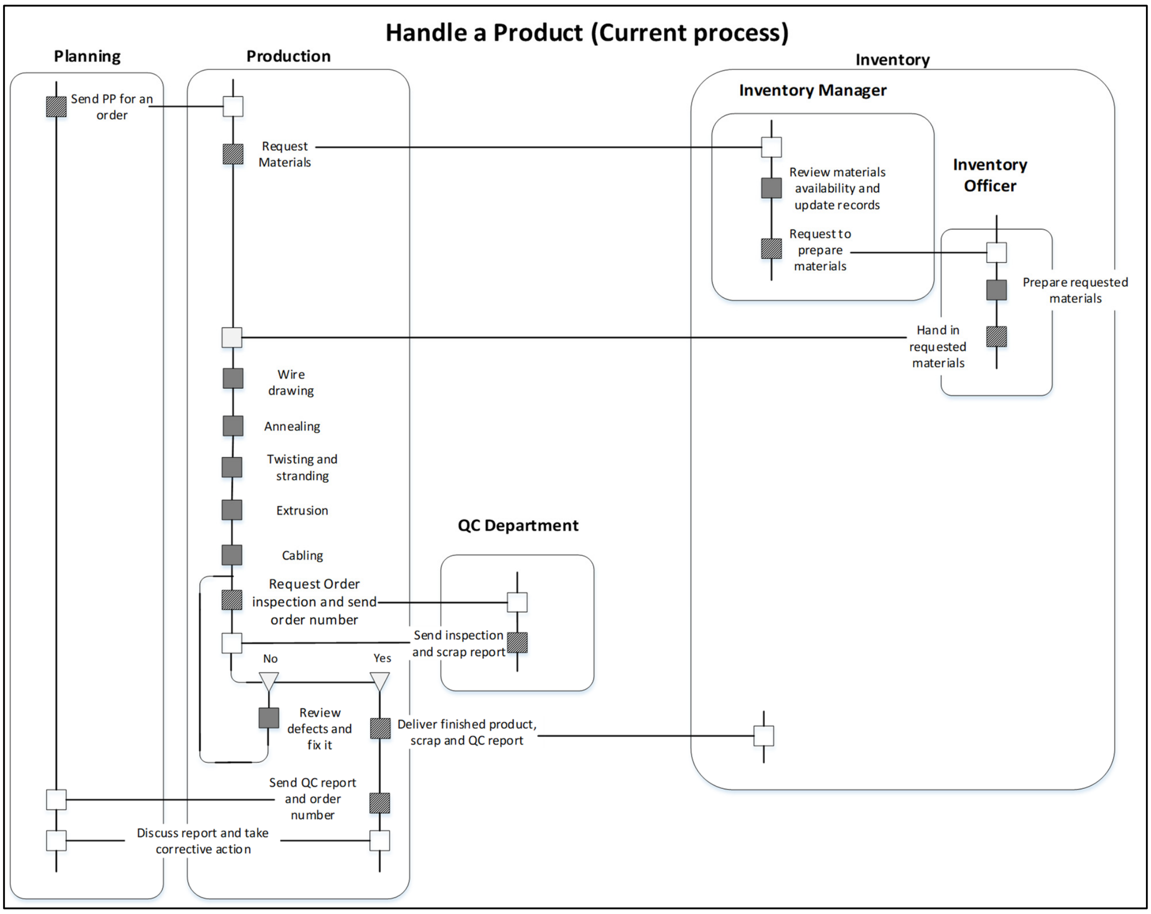

Figure 2. 'Handle a product' Current process.

Products that are approved for packing and shipping are now under the supervision of the Q.C. department. The production department receives the report from Q.C., and the order number is sent to planning to arrange the needed changes in the plan or to schedule other orders for production.

3.2. Problems in 'Handle a Product' Process

Based on data collection about the production process at INCOM Egypt, the activities in 'Handle a Product' process at INCOM Egypt are of two types: either in the operations or in the information flow. Operation activities are activities that take place by machines and labour using raw materials for production. At the same time, information about production is exchanged between departments manually. Table 3 exhibits information processing in the 'Handle a Product' process at INCOM Egypt.

Table 3. Information Processing in 'Handle a Product' at INCOM Egypt before automation.

Activity	Information Processing	Problem
Receive P.P.	Materials, time, machinery, and labours are planned manually, and the plan is sent as a hard copy to production.	Information is not accurate, contains human errors and missing some information or specific requirements in the order.
Request materials from inventory	Materials are requested manually from inventory based on the P.P.	Delays in production due to inaccurate information sent to planning department by inventory department.
Steps of production	Materials enter machines and are moved from one step to another without recording quantities.	Lots of errors because of not recording quantities of semi-finished products from one phase of production to another. Quantities of the finished product are not accurate according to the plan.
Inspection by Q.C.	Production requests inspection from Q.C. manually. Q.C. receives a request for inspection by a phone call from production informing them about the order number to be inspected.	Delay in time of inspection due to the absence of the information system. QC is not informed directly after the production is finished. Problems in receiving accurate information about the product to be inspected and the order number.
Receive inspection and scrap report from Q.C.	The report is filled manually on papers and sent directly to production to inform them about the status of the finished product.	Scrap is not correctly calculated because of missing data about the semi-finished product between phases of production. Q.C. is not able to justify the quantities of defected products and scrap. Many times, labours are not attending the production while the machines are working especially during night shifts.
Review defects and fix it	Defected products are returned to be fixed in production. Information about defected products and the quantities that re-enter production are not recorded.	Due to the lack of information about the quantities produced, defected products that are returned to production, scrap and semi-finished product, it is hard to match quantities of input materials to quantities of finished products. Also, many times defected products cannot be fixed; in this case, it is recorded as scrap not defected product to avoid penalties.
Deliver finished product, Q.C. report and Scrap to inventory	Inventory receives information from production on papers. They also record the actual quantities in their records on papers.	Manual and paperwork cause information mismatch. Inventory registers quantities manually and is subject to errors and mistakes that cause mismatching with other information in other departments like packing, shipping, Q.C., production . . . and so on.
Send QC report and order number to planning department	Information about the order status is sent manually to planning.	Planning must wait until production is finished and might also have planned production for other orders without getting informed about the status of the current order. Problems happen when defected products need to be fixed or reproduced. In this case the P.P needs to be changed before planning new orders and sending them to customers.

3.3. Proposed Improvements for 'Handle a Product' Process in INCOM Egypt

The production process is involved in the initiation of other processes, especially 'Handle a product'. Manufacturing companies need to integrate processes and information on the same technological platform to avoid discrepancies, redundancies, and errors in the information. It will also allow all users to have access to timely data and information that will assist in decision-making. Therefore, it is essential to implement a system—like ERP—that supports communication between administrative departments and production to manage the processes electronically.

The manufacturing process is currently semi-automated. In cables and wires manufacturing, machines operate raw materials with minimum human intervention, unlike harnesses that require intensive labour work. Technologies used in Industry 4.0 widely introduce devices and techniques that can eliminate human intervention in production. Information about semi-final products can be captured automatically by devices and sensors to be sent via IoT to the cloud (either private or public). Data analytics applications/software can provide reasoning and analysis accompanied by the best alternatives of solutions. Employees can view and follow up on the status of production via applications/software installed on their mobile devices or computers connected to the cloud to monitor production. Automated decisions made by the system can also be overridden if the employee requests so.

In Figure 3, while proposing the transition to automation, some activities are dropped, others are added, and some are modified, or perhaps no change occurs. Table 2 explains the changes that are needed for automation.

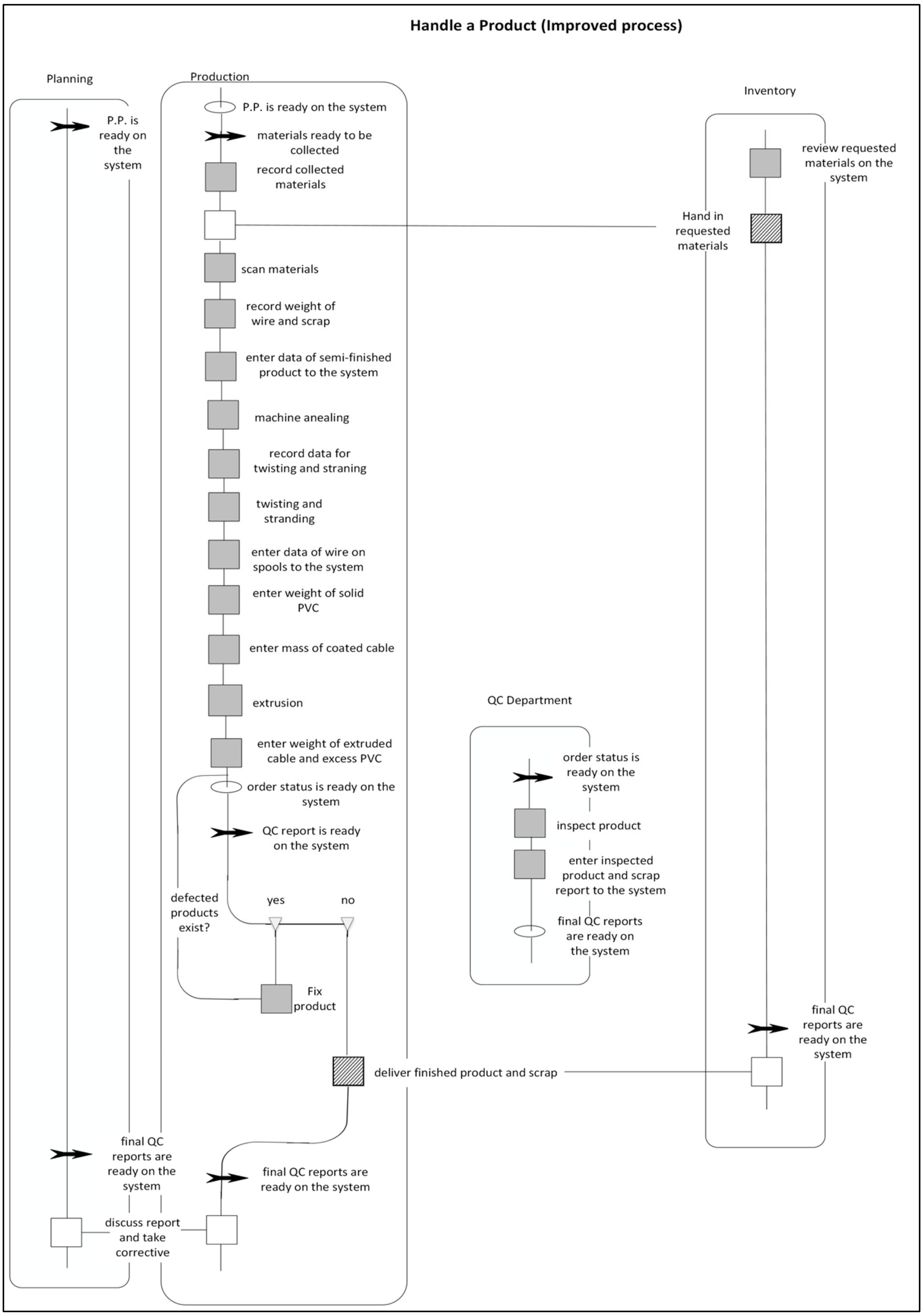

Figure 3. 'Handle a product' (Improved process).

As explained above, few activities have been added, modified, or dropped based on the early-proposed model. Hence, we conclude that the Riva method proved to be effective when applied to the production of wires and cables at INCOM Egypt to identify anomalies and inefficiencies in the production line system. The analysis is beneficial to indicate areas of automation and applicable technologies for improvements to achieve sustainability goals in terms of energy and time [43,58].

3.4. Level of Automation for the Production Process of Cables

'Handle a product' process in INCOM Egypt suffered many problems due to inconsistency in data and delays in sending the data.

After the process is analysed, it was noticed that the process needs better information flow to support its operations. Production's main problem is the inaccurate quantities of semi-final products since those quantities are not known at the beginning of the process. In addition, INCOM Egypt cannot obtain accurate calculations for the scrap and the final product. Sometimes the quantities of raw materials are not enough to produce the planned quantities as per the planning department because of not enough information about the semi-final product. Also, production might exceed what was planned because of overestimating raw materials by the planning department.

The RAD analysis of the Riva process has helped identify that the level of automation in production is limited to some information flows. Thus, the existence of a system with an Operation Module is needed to solve this problem. Production takes place in machines, but the entered and produced quantities need to be recorded on the system.

Semi-final products that used to be labelled by labour at each step of production could now be scanned by the inventory system to enter the quantities of semi-final products and the quantities of scrap. This can be phased in using parallel implementation, whereby manual processes can be phased out. Ultimately, the aim is to make sure the process is fully scannable and automated for better control.

Information flow between departments can also take place electronically so that Q.C. and Planning can view production steps on the system and follow up on the order online. In this case, information becomes accurate and will arrive on time. The Q.C. report, in this case, should be entered into the system as a record for review later.

Research Question 1: How can the use of Ould's Riva modelling help identify efficiencies in the manufacturing processes of a semi-automated factory?

The use of Ould's Riva modelling has helped identify the readability of automation for processes and activities. The modelling tool helped examine the business processes prior to process automation, steers adopted the technology. The process helped identify the required data and produce processed information of the factory, where reliable data and information are essential for the efficient functioning of the processes. Economic sustainability aims at reducing cost and improve accurate and precise information as key for cost-saving and efficiency in production. Process automation (Industry 4.0) without sufficient process planning may arrive at undesirable results because of poorly defined data and information. Therefore, analysing business processes elutriates the flow of information, and thus information, as a crucial component of a process, will be carefully examined.

For example, the quantities of required materials in the production of wires and cables can now be accurately calculated and measured, defective products are precisely counted, human intervention in data entry is eliminated, and accordingly, precise data is customised. Moreover, the importance of data and information lies in feeding big data and predictive analysis which are two key components to improve social and economic sustainability, hence proved, data and information imported from Physical Cyber Systems, Real Location Trackers, and other data capturing devices, are essential to IoT, AI, and data analytics applications. This paper has proved that a systematic review of the processes using modelling tools Olud's Riva, can help identify efficiencies in the manufacturing processes of a semi-automated factory.

Research Question 2: What are the key processes in the production of wires and cables that can be adjusted to reduce waste and improve sustainability?

Based on the above analysis in Tables 1 and 2, status and proposed improvements are drawn out of the RAD models. Modelling the production process of wires illustrates many details of the process's procedures, while it also keeps track of information flow and materials/product flow with reference to the responsible actor. Anomalies in some activities were detected, for instance, activities dropped include sending documents and reports that carry information from one role to another, whereas applications like ERP systems can share information among intended parties once entered into the system. Activities added are proposed to ensure accuracy in data and timely data flow, thus reducing anomalies in the performance and delays could be eliminated by automating data entry to the system either by a worker (semi-automated not efficient) or automatically scanned by a device to ensure availability of accurate and timely data/information. Two modifications were proposed one for recording the weight of wire and scrap and the other for conducting virtual meetings, hence related data will be available on the system while virtual meetings provide more flexibility for the undertaken activities. Unchanged activities are almost done by machine where there is no modification to happen on them or are activities done physically like carrying products or materials so the automation of those activities may incur Hight cost or might require customisation using AI.

Hereby explaining that amended or dropped activities as shown above proved that process modelling technique such as Riva method demonstrates sufficient analysis for the wire production process to remove some anomalies and inefficient/unnecessary activities for improvement.

The previous analysis and the proposed improvements were introduced to key persons at managerial levels at INCOM Egypt to get feedback about how satisfactory the changes are to solving some problems at INCOM Egypt in wire production. Their feedback was an endorsement of the improvements which were seen as a great advancement that could be implemented in phases due to the high cost of technology and the readiness of workers to the change. Thus, Table 4 has successfully outlined the key processes that can be removed, adjusted, or added to reducae waste and improve sustainability of the manufacturing process of the company. The key processes can be summarised as: automation of orders, scanning of input materials, reuse of preapproved designs, live reporting of processes before finishing, and better management of raw materials. Equally important is the dropping of redundant human to human communications that are open to human errors.

Table 4. Information Processing in 'Handle Product' at INCOM Egypt after automation.

Activity in the Production Department	Action	Reason of Action	Impact of Action on Sustainability
Send P.P. of an order (current)	Dropped	P.P. is already created on the system and is shared by the intended departments.	Improve time management as time is factor of sustainability [58], Improve accuracy and accessibility of data [59]
Request materials (current)	Dropped	The request includes quantities, time, and date of production according to the plan. Reduce corruption and time delay by accessing precise data on the system.	Improve time management as time is factor of sustainability [58] Improve accuracy and accessibility of data [59]
Record collected materials by production	Added	Apply barcode scanning at the production department while materials are collected from inventory to track work-in-process materials.	Improve accuracy and accessibility of data for decision making concerning inventory levels. [59] Control materials, thus costs and inventory turnover.

Table 4. *Cont.*

Activity in the Production Department	Action	Reason of Action	Impact of Action on Sustainability
Move collected materials to workshop (current)	No change	Materials are physical products that require human intervention to carry them from one place to another, and automation of this activity can be expensive, and in some cases, automation is not out yet.	No action taken.
Scan materials used in production to update the system using scanning devices, (proposed)	Added	Information about materials needs to be entered into the system to be tracked and analysed easily. This activity requires a scale to weigh copper, PVC, and empty spools also a bar code scanner to capture the batch number and send it to the system/cloud for record-keeping and analysis.	Accurate, timely, and precise data improves decision taken towards sustainability [60]
Wire drawing record weight of wire and scrap (proposed)	Modified	Use built-in vernier caliper to record length, and diameter of a wire, also use a digital mass scale to measure the mass of wire and scrap. All data will be recorded on the system.	Data integration between planned and actual materials consumed in production. This supports cost effectiveness as a criterion of economic sustainability.
Enter semi-finished product information before annealing on the system use thermometer to record initial temperature (proposed)	Added	Read data from the machine about the length and diameter of wire drawn in addition to temperature reading and send it to the cloud via an Internet connection.	Enhances the quality of the product, accordingly, reduces defective products thence, enhancing both environmental and economic sustainability.
Annealing (current)	No change	Machine process	No action taken.
Enter product data for twisting and stranding on the system, use thermometer to record final temperature (proposed)	Added	Read data from the machine about length and diameter of wire drawn in addition to temperature reading and send it to the system/cloud via Internet connection.	Enhances the quality of the product, accordingly, reduces defective products thence, enhancing both environmental and economic sustainability.
Twisting andStranding (current)	No change	Machine process	No action taken.
Enter data of twisted wire on spools to the system using mass scale (proposed)	Added	Use a mass scale to read the mass of each spool and record data per spool while counting the number of data entries as equivalent to the number of spools.	Data of work-in-process materials can be tracked to control inventory. No direct impact on sustainability, however, traceability of materials could be attained.
Cabling: enter weight of solid PVC to the system (proposed)	No change	Machine process	No action taken.
Enter mass of coated cable/wire using a digital scale proposed)	Added	This process will allow the weight of twisted wires and coating PVC to be recorded for further calculations to be compared to initial figures of materials for quality control and monitoring waste of resources.	Data integration between planned and actual materials consumed in production. This supports cost effectiveness as a criterion of economic sustainability.
Extrusion (current)	No change	Machine process	No action taken.

Table 4. *Cont.*

Activity in the Production Department	Action	Reason of Action	Impact of Action on Sustainability
Enter weight of extruded cable and the excess PVC after extrusion (proposed)	Added	The weight of the final product is recorded to the system using a digital mass scale. The same is to be done to the excess PVC after extrusion. The total weight should be compared to the initial figures of materials used for quality and sustainability purposes.	Data integration between planned and actual materials consumed in production. This supports cost effectiveness as a criterion of economic sustainability.
Request order inspection and send order number to Q.C. (current)	Dropped	Accurate information about the finished product and order number is already on the system, no need to request and inform Q.C. for inspection.	Saves time, improves safety, and saves cost that positively affects environmental and economic sustainability.
Q.C. department sends inspection report and scrap report to production department (current)	Dropped	All reports are filled online.	Saves time and cost that positively affects environmental and economic sustainability.
Review minimal defects and fix it (current)	No change	Human and machine process	No action taken.
Deliver Q.C. report to inventory (current)	Dropped	QC report is located on the system.	Saves time and cost that positively affects economic sustainability.
Deliver finished product and scrap to inventory	No change	Physical product and scrap need to be delivered physically to inventory.	No action taken.
Send QC report and order number to the planning department (current)	Dropped	The planning department can view the QC report on the system.	Saves time and cost that positively affects environmental and economic sustainability.
Discuss order and take corrective action (current)	Modified	Production and planning departments need to virtually meet and discuss how the plan worked out.	Virtual meetings are convenient for employees to join remotely which saves time and can be recorded for future review. No direct impact on sustainability.

Research Question 3: How can process improvement and automation positively affect environmental and economic sustainability in the production of cables and wires post COVID-19 pandemic?

Improvements in wire production are based on Industry 4.0 technologies that are proposed to limit or eliminate human intervention. The use of technology supports two areas in production; the flow of papers/documents that will be replaced by systems that maintain the digital flow of information and the physical activities that require the presence of workers to handle them including data entry in some cases. The later could be supported by digital devices like scanners, sensors, and AI. The digital flow of information will eliminate the use of papers, provide timely and precise information that could be shared among departments and enhance decision making. Accordingly, this saves money in achieving economic sustainability. While automation of physical activities results in minimising the number of employees/workers intervention ending up to efficient and effective processes. Consequently, the reduction of waste could be achieved as a goal of economic sustainability.

To summarise, the above analysis shows the importance of process modelling using a technique like Riva to explore the activities undertaken in the process, define anomalies and propose improvements (technological and non-technological) that assist in achieving sustainability goals [61]. This research focuses on technological improvements in the production process of wires and cables relying on Industry 4.0.

4. Discussion

The process of 'Handle a product' is simple if the company has the machines needed for production. INCOM Egypt is facing lots of problems in finance and production caused by inaccurate information. The planning of production has had several challenges, including inaccurate estimates, defective products, and scrap quantities exceeding the allowed percentage because of corruption and the lack of an appropriate information system.

Focusing on sales of INCOM Egypt, the indicator signifies a potential and optimistic position in the market. However, the unfavourable positive correlation between sales and COGS, in this case, is preventing the company from improving its financial positing and attaining sustainability. Hence, the paper recommends that adopting sustainable technologies would play a major role in enhancing the financial performance by decreasing costs instead of adding pressure and financial stress as shown in the current scenario of the company.

The preceding scenario at IncomEgypt has caused mismatch and inaccuracy in financial analysis, planning analysis, inventory analysis, and providing inaccurate delivery time. The use of Riva has helped in identifying the key challenges, namely data entry, sharing of data among departments—to control the financial situation—and data accuracy. Despite process automation becoming common in most industries, there is always a need to systematically analyse the readability of the process for automation. Moreover, data and information need to flow through these systems without human intervention to evade errors that can lead to inaccurate decisions. The method used to analyse the production process of wires and cables in this research aims to evaluate the possibility of using electronic devices based on the latest technology to capture data automatically and send it to the cloud. These are then imported into decision-making software so that automated decisions can be made. Those devices should also be able to receive orders to adjust the machines while production is taking place. Moreover, devices need to be connected to the cloud to make the data available to everyone in production that will also be accessed via an application. Decision-makers and key persons will be able to monitor the production at any time and from anywhere using the application on their devices. They should be able to change the decision made by the system or accept it. The benefit of automation in Industry 4.0 lies in reducing cost, time, and effort, where the three-affect sustainability if they are managed correctly.

Based on the proven relationship between industry 4.0 and sustainability, as reviewed in the literature section, the automation of production processes positively affects sustainability. Considering recent events due to the COVID-19 pandemic, economies worldwide have deteriorated, including that of Egypt. Therefore, technological advancements in production need to be handled innovatively via remote operations by utilising Industry 4.0 and automating processes.

According to [55], process modelling reinforces process automation in the production of wires and cables. Furthermore, Industry 4.0 reinforces sustainability, and based on the previous analysis of the production process of wires and cables that explored the areas where automation is feasible, it can be concluded that process modelling is a key principle to achieving sustainability. In other words, automation of processes does not guarantee to support sustainability. In this case, the proven relationship between Industry 4.0 and sustainability by [56] needs to be integrated with process analysis. The relationship between process analysis and sustainability, as mentioned by [11], can also be generalised to other lines of industry. Thus, the three approaches reinforce each other, and accordingly, there is a triangulation between process modelling, process automation (Industry 4.0), and sustainability, as depicted in Figure 4.

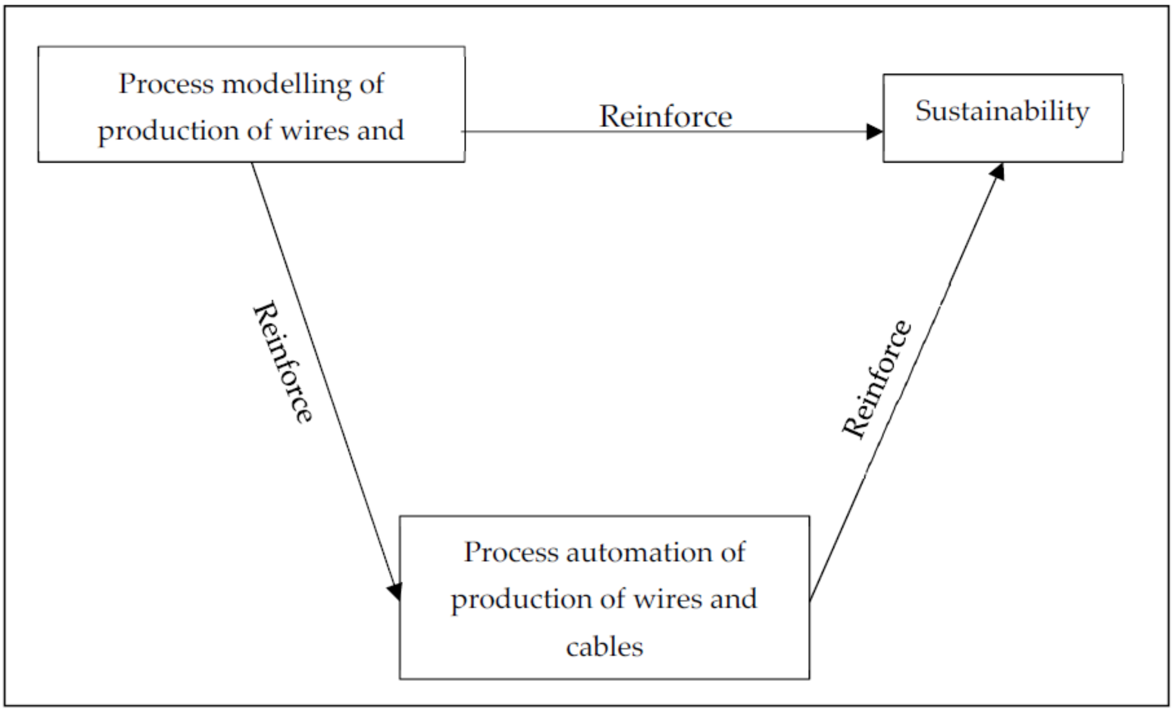

Figure 4. The relationship between process modelling and sustainability.

As this paper has proved that automation of the production process in the wires and cables industry can positively affect sustainability, there is a need to consider moving towards automation in production in other areas of manufacturing. But not all improvements have a positive impact. Some proposed improvements were found to have no direct impact on sustainability. The automation of these activities is essential to integrate the information system and the flow of information electronically. Excluding automation of these activities will distort the functionality of the information system leading to defective production and unnecessary waste. While production processes need to be investigated to understand the flow of information and the activities done by each role, business process analysis/modelling is vital to detail business processes for improvements using Industry 4.0 technologies serving as a platform for automation. As a result, this will support sustainability. Lessons could be learned from this approach and drawn concerning other manufacturers. Based on [38], organisations in the same line of business should have the same processes. Accordingly, improvements in one organisation should also apply to others in the same line of business.

The severe restrictions imposed by the governments after the COVID-19 pandemic, call for utilisation of Industry 4.0 technologies in the production of wires. Table 4 analysed areas where technological improvements are found to be effective and applicable. Automation of production leads to better sustainability. However, not all processes/activities support technology as well some activities still cannot be automated, and therefore, process analysis is required to examine the applicability of the technology in the process for reengineering.

5. Conclusions

The current research explored the activities, roles, and information flow in the production process of wires and cables. Each activity in the process was examined to map technological improvements to the activities of the process and to elucidate information pertaining to each process. However, the research did not tackle statistics of time and cost savings due to the limitation of time. One more limitation faced by the researchers is to calculate the cost of technological advancements and compare it to the benefits of sustainability. Therefore, financial sustainability can be completed in future work. Moreover, it was hard to collect data from employees due to time constraints while they are at work and their limited understanding of the purpose of the research, especially sustainability.

The future work will examine time, preciseness of data, and cost-effectiveness in terms of numbers in relation to the analysed activities and data. The research will compare the measurements of the process before and after automation so that the findings will serve as KPIs to measure the relationship between automation (Industry 4.0) and environmental economic sustainability.

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Institutional Review Board Statement: While the study did not have human or animal study part of its process, informed consent was obtained from the company involved in the study. Written informed consent for publication must be obtained from participating patients who can be identified (including by the patients themselves). Please state "Written informed consent has been obtained from the patient(s) to publish this paper" if applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to the confidentiality and privacy of financial documents related to the company.

Conflicts of Interest: The authors declare no conflict of interest.

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