Optimizing Distribution Processes Using Industry 4.0 Technologies

Hilal Chehab
Department of Industrial Engineering and Management
American University of Beirut (AUB)
Beirut, Lebanon
hhc08@mail.aub.edu

Rayan Idriss
Department of Industrial Engineering and Management
American University of Beirut (AUB)
Beirut, Lebanon
rmi27@mail.aub.edu

Hassan Mahaidli
Department of Industrial Engineering and Management
American University of Beirut (AUB)
Beirut, Lebanon
hsm19@mail.aub.edu

Mohamad Younes
Department of Industrial Engineering and Management
American University of Beirut (AUB)
Beirut, Lebanon
myy05@mail.aub.edu

There is an evident lag in the adoption of new technologies within Lebanese companies, regardless of the industry type, especially when it comes to data exchange and management operations. Today's available tools can make the process of extracting and utilizing suitable information an effortless task. All it needs is proper organization and mapping through Industry 4.0 technologies. Our project aims to push Wafic Idriss Ets., a Fast-Moving Consumer Goods producer and distributor, towards the implementation of this trend by creating a smart environment of completely automated data exchange. This transformation requires that the environment undergoes an overhaul since the data on-hand is either on paper or has been digitized poorly. Several steps towards reaching this milestone have been achieved, such as cleaning the data, creating a Microsoft Excel application with executable macros, and developing a Microsoft Access interface with appropriate forms that display all information needed for the distribution operations. In the second part of this project, we designed a software robot dedicated to facilitating data transfer between the two platforms. We also developed a mobile application that makes use of the newly formed database. It organizes the drivers' daily deliveries based on client locations, monitors the status of deliveries, and updates the database after completing an order. The application uses Google technologies to guide the drivers to use the best possible routes to reach each customer and provides them with an incentive to complete more jobs, therefore increasing their productivity. The results of the project will be analyzed through the robot's performance by assessing reduction in time spent to run daily tasks, and the application's ability to increase productivity, therefore minimizing overall costs spent on our industry partner's delivery sector.

Keywords: *Internet of Things, Robotic Process Automation, FMCG, Industry 4.0, Digitization, Data Management.*

I. INTRODUCTION

The digitization and interconnection of supply chain processes have become essential to businesses in today's industry. The rapid advancements in technologies and applications in various industries have helped in increasing productivity. These advancements are part of what is called the fourth industrial revolution. It revolves around introducing new ways to manage supply chains, to combine and integrate their different elements through flexible tools with the goal of continuous improvement [1].

To sustain their competitiveness in a globalized environment, organizations must consistently evolve their systems to accommodate the changing needs of their markets. Companies that do not keep up will fall behind [2]. As the world is diving deeper into this realm, we find that Lebanese companies who adapt to this change at an early stage will benefit by gaining an advantage over other local competitors. Such is the case in the grocery sector as many supermarkets are integrating technology in their operations to remain competitive (e.g. online delivery). This is why we decided to work with Wafic Idriss Ets. (WIE). It is a well renowned Fast-Moving Consumer Goods (FMCG) producer and distributor in Lebanon. It has been in the market for over 80 years and has become a leading commercial and industrial group. During the past decade, it has been growing and proving itself in the Lebanese market, gaining market shares through its locally manufactured products and a wide spectrum of imports. These products range from food items (Dolly's, Chtaura Frozen Foods, etc.), to non-food items (cleaning supplies and pet food). The establishment does not manage the delivery of its products but instead, outsources this service to Beirut Cargo Center (BCC), which is responsible for delivering the orders to the customers. BCC has an office on the WIE premises and has been working with them for the past nine years.

Even though our industry partner has already established itself in the market, its main issue lies within its capability to optimize its daily delivery operations, as they report many lost orders and customer complaints due to delays and inefficiency of the distribution department. The distribution industry in Lebanon is witnessing penetration attempts by small entrepreneurs. These start-ups are infusing this sector with digitized systems that closely monitor their operations to collect data that is used to continuously improve. Our industry partner wants to maintain a strong presence in the FMCG

industry by integrating these tools and capitalizing on its massive, untouched database.

The management at WIE was looking forward to having us integrate Industry 4.0 technologies within their operations. WIE executives were hoping to reduce their cost of operation, which matched our goal of integrating digitization, as it has proven to have a huge economic sustainability impact when integrated into an FMCG company [3].

These processes are found to be inefficient and very time-consuming. Switching to a digital format can help boost productivity and minimize the processing time of an order [4]. It is beneficial to have the data available instantaneously, as it minimizes the costs of physically printing and transporting the data. This has proven to be advantageous for companies' decision-makers as it allowed them to gather all the facts they need to analyze the company's performance while aiming to improve it [5]. We were driven by integrating automation into our work as pairing it with Lean Production philosophies is a promising and contemporary aspect that can be implemented in technology-driven environments [6].

II. Goals and Objectives

This project aspires, on one hand, to help WIE in exploiting the data it possesses and hopefully turn it into useful information. On the other hand, it aims to help minimize the time it takes to work with data by eliminating its manual manipulation and replacing it with a smarter environment.

The operation we worked on optimizing goes as follows:

1. WIE receives orders on their Enterprise Resource Planning (ERP) software. A Sales Order number (SO) is assigned. An invoice is generated based on available inventory.
2. The invoice is sent back to the sales team where it is revised accordingly. Once all invoices are received, they are transferred to the BCC.
3. After receiving all the invoices, the BCC starts the routing process by hand. Orders going to similar destinations are grouped under a unique manifest
4. The next day, early in the morning, each truck driver arrives at the BCC and receives a manifest number of which they are responsible to deliver. Trucks are then loaded accordingly.
5. BCC manually enters each delivery's details into an Excel monthly report that is later sent to WIE.

A. Data Management

We first gained access to Excel files reporting the status of previous deliveries. As we went through with them, we were prompted to shift our aims to develop data storing and entry programs. Ideally, this system would be split into a preliminary data entry program that is updated daily, linked to a long-term storage database. The main reason for this decision was the inefficient data entry process.

To fully digitize this system, we also focused on programmable automating tools to facilitate data entry. Robotic Process Automation (RPA) is one method that can suitably implement the integration of automation. This is achieved by mapping out the steps performed by human operators and develop a software robot to execute the same tasks. The leading platform in this industry, UiPath, allows the rapid execution of software robots, which dramatically increases productivity, compliance and customer service in both back-office and front-office operations [7]. In our case, the goal is to build a robot that can extract sale orders to store them in their suitable locations, easing database management and simplifying the decision-making process.

B. Delivery Process Optimization

After improving the data entry and storing process, we intended to work on delivery and routing optimization. We discovered that vehicle routing is done by human force, a day prior to deliveries. Given that this process depends heavily on soft knowledge and has no clear assessments of its efficiency, it is prone to errors. This soft knowledge was difficult to document as it was based on close to a decade's worth of experience that the employees have attained. In addition, workers often rely on instinct due to the many variables that should be taken into consideration. Gathering and making use of such data is, therefore, a priority of ours as we wanted our overall system to implement Kaizen principles and continuously improve. We also found that our industry partner possesses a substantial amount of data that is untapped: unused vehicle tracking data that can be used to optimize the routing process, delivery shipment timing that can pinpoint where exactly delay is occurring, etc.

Pairing that with the Fun Theory proposed by Wenner, "a concept built around making jobs or actions fun", we focused on trying to "gamify" the delivery task by giving workers sensory feedback upon each successful delivery, boosting their sense of accomplishment and, on the long run, making them more productive [8]. This pushed us to develop a mobile application that the truck drivers will rely on to figure out their tasks, destinations and optimal routes to take. This will also allow us to document exactly the time it takes to perform the deliveries and thus be able to pinpoint the specific reasons that cause delays

III. Background

The fourth industrial revolution is an enhancement of its predecessors that were centered around mechanization, mass production, and autonomation. Many of the tools utilized today such as computers, software, and automation have been around for a while, but it is the Internet that revolutionized their use. This led to the birth of the Industrial Internet of Things (IIoT), which refers to the ability to interrelate all parts of a process without needing human interaction. This allows for improved data collection, exchange, and analysis. Some of those aspects were brought into the supply chain, such as simulation, RPA, cloud-based services, and others [9]. This led to a substantial decrease in handling and shortage costs, in addition to improved inventory management [10].

The end goal of the management of logistic operations is related to fulfilling customer demands on time and providing them with services of the highest quality. This would improve a company's positioning in the industry, which is why the decision of incorporating technological tools in logistical functions of the company is crucial for its success [2]. New technologies have already been incorporated into logistics to both facilitate and accelerate the processes (such as Transportation Management System and Tracking). Building logistics networks with digital technologies allows companies to provide customers with the most efficient delivery services [11] and improve their performance. Using

such analytic technology helps companies save money. Digitization in logistics is expected to provide up to $1.5 trillion in added profit in the year 2025, in addition to reducing as much as 10% emission [12]. Digital logistics is based on four key main aspects: technology, process, organization and knowledge [13]. When integrated, these aspects ensure consistent and sustainable transportation networks which would make the supply of goods efficient and supply chain more robust. A connected supply chain can adjust and accommodate when new information is presented thus making it self-adaptive. (E.g. if a weather delay ties up a shipment, a connected system can proactively adjust to that reality and modify shipping priorities) [14].

IV. METHODS

We visited the company warehouse in Hazmieh biweekly in order to monitor the delivery operations and conduct interviews with workers, managers, and senior executives.

These interviews helped gather important soft knowledge on the delivery process and emphasized its dependency on the presence of specific workers. Moreover, they gave us a crucial head start towards working on each objective with a clear idea of what to focus on.

A. Organizing the data entry

The main apparent issue is that this process is outdated and cannot cope with the fast-growing size of the company and its increasing demand. The processes rely primarily on manual data entry and physical data storage. This escalation of duties is prone to human error, and, in most cases, results in inaccurate, false, and even corrupted data.

Most of the data, such as invoices and manifests are available in paper format only. In addition to that**,** the order data is stored in Excel files that have no data validation or restriction in any way. We decided to keep using Excel as the data entry platform since it has built-in features that are optimal for this process (i.e. macros, link to Microsoft Access, etc.). Our work began by building the necessary sheets and data validations in Excel. We created three sheets to represent the three possible states of an order: “Received”, “In-Transit”, “Delivered”. We implemented macros that allow the transfer of data from one sheet to another. The first button confirms that a placed order is now “In-Transit” and requires the user to input the driver name and truck number. The second button transfers the order details from “In-Transit” to “Delivered” and calculates the total transit time. We also built some data restrictions: Sales Order is entered as “SO” followed by a unique seven-digit number, the driver’s name must be selected from the list of available drivers, etc. Our Excel file was thus complete. However, in the long term, this data needs to be stored in database software. For that, we used Microsoft Access.

B. Creating an online database

The next step consisted of building the Access database and its interface. At this stage, we were granted access to the company’s dataset, that contained the driver information, the truck details, and previous delivery details. However, similar to what we had witnessed with the files we previously handled, there were many errors and discrepancies. We allocated the first two weeks to clean the data. We kept double-checking with our liaison in the company for confirmation. We then worked on designing tables based on the Third Normal Form (3NF) principles.

After cleaning the data, we started building the Access Entity-Relation (ER) diagram that linked all the tables together. We consulted our industry partner about which aspect of the data should be easily accessible, so we built the queries and the interfaces accordingly. It includes but is not limited to identifying the driver of each truck on a given day and the manifest it had loaded, all the orders of a specific customer, and the orders that had been in transit for more than three days.

Therefore, as we had planned, our work organized the data into two parts:

- The daily collected details stored in Excel and directly available in case any error or accident happens;
- The Access database to which the above-mentioned information is imported and stored for safekeeping and performing queries.

C. Facilitating data entry

We realized that constantly importing data from Excel to Access is not a simple task for the average worker. That is why, to simplify this step, we built an automated software robot using UiPath. This robot mimics the steps the employee must carry out. To develop this robot, we had to carefully map out the process, click by click, while ensuring minimal variability. When the robot is orchestrated, it performs the job of opening the Access file and importing the daily data from the suitable Excel file, which contains several sheets. The robot executes these steps faster, eliminating the need for a human operator. It would also archive Key Performance Indicators (KPIs) into a dedicated Excel sheet tailored for robot monitoring. The robot would ideally perform the job unsupervised once after the end of each operating day, updating the Access database with suitable records. Human intervention is only needed if the Excel sheet dedicated to KPIs contained any alarms of failing jobs performed by the robot.

D. Simplifying data collection

Our next step was to take care of the delivery process itself. To "gamify" this task, we were faced with two alternatives: either implement a physical button within each truck, or a virtual one via a mobile application. Our industry partner was pushing towards the idea of the physical button as they did not want to use the drivers' personal cellular phones with work-related tasks mentioning that some of the drivers did not even possess smartphones.

However, after careful consideration of both options, we found that it was more cost-efficient to equip each driver with a job-dedicated smartphone (a smartphone Huawei Y9, costing $99[1]) than to equip each truck with a button.

TABLE I. PRICE BREAKDOWN OF BUTTON COMPONENTS

Button Component	**Cost[a]**
Raspeberry Pi GPS	$60.00
Raspberry Pi Kit	$58.00
Button Case	$2.00
Total (per button)	$120.00

[a.] Prices from EKT, Lebanon

[1] Price from 3gleb.com, a smartphone retailer in Lebanon

It is substantially cheaper and more reliable to design a mobile application than to build a physical button and to mount it on the trucks.

After meeting with the company's COO to discuss our next steps, he agreed to let us shadow some of the truck drivers. By doing that, we were able to collect accurate coordinates for some of their customers by using our personal smartphones and documenting these locations.

Having acquired the customer locations and finally completed our database, we were able to develop the application. To truly digitize the delivery process, we took the application beyond its scope of just being a virtual gamifying button and turned it into a delivery checklist. It gets its data from the "In-Transit" sheet in the Excel file previously mentioned, now synced with Microsoft OneDrive.

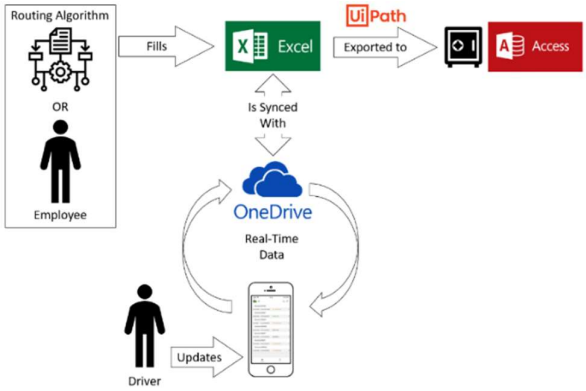

Fig. 1. Chart explaining the connections between the different interfaces.

V. Results

Our first deliverable was the Excel file which helped the operator store the data. We tested out this data management system with our industry partner for two weeks. It took time to familiarize the employees with this new system. However, after reviewing the outcome, we observed no discrepancies or errors, in contrast with the multiple errors observed in previous files. Based on employee feedback, the data was easier to manipulate and took less time to manage. One specific employee mentioned that the routing task that usually took him up to three hours was reduced to take around fifty minutes.

The Access file has proven to be beneficial as the supervisor can now instantaneously find the information they need whether it is related to a specific customer, order, or manifest. This is all achievable due to the queries we built around the several data entities which are the customers, the trucks, the drivers and the orders. The supervisor can now indicate which data they want to analyze and by displaying only that data at once, it has become easier to interpret, as we have been told by an employee at WIE.

Our robot needs exactly 1.2 minutes to import the Excel data into the Access file every time, and, since this is a programmed task executed by a computer, it is reliable has minimal variability in time (variations in dataset size). Attempting to execute the same task by one of the company's employees familiar with the Microsoft Office environment took around seven minutes on average, with occasional errors. This emphasizes the speed and reliability of the robot.

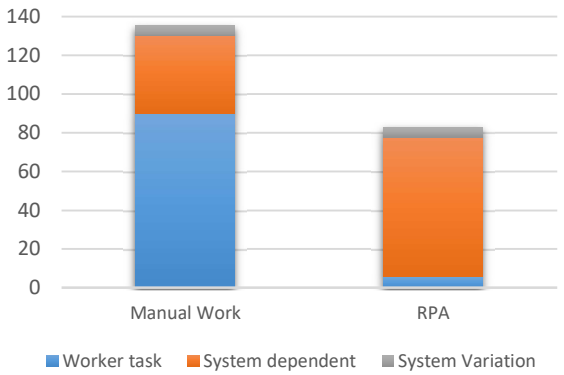

Fig. 2. Histogram comparing duration (in secs) to import data from Excel to Access (KLM used to asses the time required by a human worker).

In addition to that, the robot also eliminates most of the sources of human error as it gives no room for typos or misclicks.

As for the mobile application, it was gradually designed around employee needs and has been getting positive feedback at every update. However, at the time of writing of this paper, the application has still not been tested on the drivers. The platform functions as follows:

1. The driver logs in with their credentials;
2. A "Jobs" tab displays the list of jobs to be accomplished (older jobs are prioritized and are more salient);
3. A "Map" tab displays all currents jobs on a map, allowing the driver to know beforehand which areas they will be visiting;
4. Tapping on a specific order takes you to its details (client name and code, location, date of order, Job ID, and the items ordered);
5. Tapping on the coordinates shows you the location of the customers and the optimal routes to take (using Google Maps);
6. Orders are updated based on their status (not started, in progress, completed, or blocked);
7. A job is officially completed when the retailer inputs their E-signature.

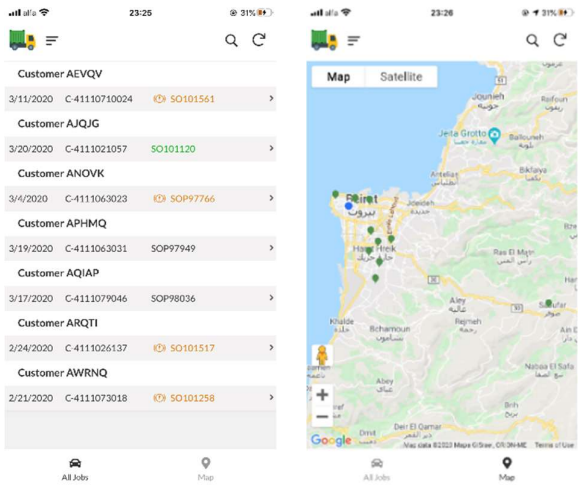

Fig. 3. Screenshots from the application developed for the truck drivers.

According to WIE management, the most crucial piece of information in any delivery is the time spent at the customer site. Its importance stems from the fact that they have close to no control over how long it is taking to unload and hand over the merchandise. Implementing this application will allow them to monitor the exact duration of this task and will be able to flag any outliers.

This app also allows the backend user to have live updates on the status of each delivery. It allows us to implement a form of autonomation, effecting the principle of Jidoka: all irregularities within the delivery process are to be flagged. Given that monitoring the drivers is now facilitated, superiors within the company will be able to take proper measures and know exactly where delays lie. On the other hand, drivers are encouraged to complete more orders in less time given that their efforts are now more noticeable.

VI. Discussion and Conclusion

This project exposed us to real-life problems where we had to develop our own solutions to certain issues, test them, and on many occasions, fail and return to building from scratch. The results we achieved impressed our industry partners, as they began to realize how most of their processes were outdated. They became motivated to update other departments to maximize their profit and not lose their competitive advantage over the new competitors that are using new technologies. The data storing program that we implemented in WIE may be viewed as basic as it only uses Excel and Access; however, these two programs have been built and tailored to best suit the company's operations.

Within the academic year of working on this project, Lebanon faced many disruptions that impeded the ability to commute properly. Starting from a revolution that was accompanied by road closures to the COVID-19 outbreak, the circumstances left us with an obligation to work remotely for the most part. We had to focus on deliverables and objectives that could be completed with minimal visits to our industry partner's warehouse. Moreover, we dealt with a budget limitation that led us to seek methods and tools of the slightest cost.

Our greater objective was to build a system that takes into consideration all the soft knowledge that the employees possess (such as time to unload the items, the opening hours of each customer and the occasional traffic based on timings). A system that automatically groups and forms the manifests based on all the orders and the number of available trucks. In addition, it would use Google Maps and display the optimal routing for the drivers. This program would be then linked to the mobile application we developed for the drivers. Human labor would then be reduced to minimal efforts, as the only task remaining would be to monitor the process, assure all the programs are running smoothly, and intervene in case of any errors.

Our next target will be focused on developing a routing algorithm that depends on data that the company has already gathered but does not use (such as delays in deliveries, truck routing, and delays that occur during transportation due to traffic or other incidents). We also aim to enhance the mobile application in order to have all the data updated instantaneously.

The achieved objectives form a reliable base from where we can continue building upon. Once the mentioned algorithm is complete, running enough tests would be all that is left for this project to live up to its title. We would have applied what was suggested throughout the beginning of this report: integrating digital logistics through data and process mining tools for the sake of quality control, efficiency, and maintaining market strength.

VII. References

[1]. Abdel-Basset, Mohamed & Gunasekaran, M. & Mohamed, Mai. (2018). Internet of Things (IoT) and its Impact on supply chain: A framework for building smart, secure and efficient systems. Future Generation Computer Systems. 86. 10.1016/j.future.2018.04.051.

[2]. Barreto, Luis & Amaral, António & Pereira, Teresa. (2017). Industry 4.0 implications in logistics: an overview. Procedia Manufacturing. 13. 1245-1252. 10.1016/j.promfg.2017.09.045.

[3]. Kayikci, Y. :Sustainability impact of digitization in logistics. *Procedia Manufacturing"*, (2018)

[4]. Adobe Keynote, Document Drain: How Back-Office Processes are Shredding Productivity, 2016

[5]. K. Chen, A. Kannan, Y. Yano, J. M. Hellerstein, and T. S. Parikh, Shreddr: pipelined paper digitization for low-resource organizations, Proc. 2nd ACM Symp on Computing for Development (DEV), 2012.

[6]. Kolberg, Dennis, and Detlef Zühlke. "Lean automation enabled by industry 4.0 technologies."IFAC-PapersOnLine48.3 (2015): 1870-1875.

[7]. Madakam, Somayya, Rajesh M. Holmukhe, and Durgesh Kumar Jaiswal. "The Future Digital Work Force: Robotic Process Automation (RPA)."JISTEM-Journal of Information Systems and Technology Management16 (2019).

[8]. G. Wenner, M. Marino, E. Obeysekare and K. Mehta, "Making data collection in low-resource contexts intuitive, fun, and interactive," IEEE Global Humanitarian Technology Conference (GHTC 2014), San Jose, CA, 2014, pp. 49-56.

[9]. Rüßmann, M.; Lorenz, M.; Gerbert, P.; Waldner, M.; Justus, J.; Engel, P.; Harnisch, M. Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries; Boston Consulting Group: Boston, MA, USA, (2015)

[10]. Heynitz, H.V.; Bremicker, M.; AmadoriI, D.M.; Reschke, K. The Factory of the Future; KPMG AG: Amstelveen, The Netherlands, 2016

[11]. Industry 4.0: How Digitization Makes the Supply Chain More Efficient, Agile, and Customer-focused, PWC, White Paper, 2016.

[12]. Digital Transformation of Industries: Logistics Industry, World Economic Forum White Paper, 2016

[13]. M. Stuermer, G. Abu-Tayeh, T. Myrach, Digital sustainability: basic conditions for sustainable digital artifacts and their ecosystems, Sustain Sci 12 (2017) 247-262.

[14]. J.M. Owen, The Scientific Article in the Age of Digitization, Springer, The Netherlands (2007)

[15]. Anagnoste, Sorin. "Robotic Automation Process-The next major revolution in terms of back office operations improvement."Proceedings of the International Conference on Business Excellence. Vol. 11. No. 1. De Gruyter Open, 2011