Demonstration of Supply Improvement of Crop Protection Materials

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Abstract

Presented study focused on supply improvement of agricultural pesticides at Adama Agan Ltd., a global leader in crop protection. The objective was to reduce logistics costs from main enterprise from $34M by 20%.

After massive data collection process mining tools identified that the main cause would be the supply gap of 12% of late orders, which highly affects logistics costs. Therefore, methods aimed to increase on-time orders' rate supply by 8% (from 78% actual) and increase SLA. The main gaps identified at the company's packaging facilities. The average time for order processing was 96-days, almost double of required. LEAN recommendations increased capacity per shift, packaging according to the EDD scheduling method reduced the number of late orders and economic evaluation for 3 alternatives facilities showed that adding a packaging facility was the most profitable.

Implementation of full recommendations will reduce the rate of late orders by 14%, increasing the supply measure to 98.6%. Adama will save $12.9M in logistics cost and thus will reduce current expenses by 62%, better than targeted 20%. This case used the methods in a distinctive way, so other companies with worldwide logistics can learn from it and improve complicated supply chain measures to reduce logistics costs.

Keywords
Lean management, Scheduling, Process Mining, Linear programming, SC cost reduction

1. Introduction

Adama Agan Ltd. is a global leader in crop protection, providing solutions to farmers around the world to combat weeds, insects and disease. The present study focused on supply chain improvement of agricultural pesticides from enterprise organization production (located in Ashdod). The main motivation was the high logistics costs of $34M yearly versus targeted $23M. Methodology included process mining, scheduling methods, linear programing, LEAN management improvement and economic feasibility evaluations. Data gathering included interviews and massive data collection from information systems.

The initial study identified that the main cause would be the supply gap of 12% of late orders (from SLA of 10% allowance), which highly affects logistics costs. Using a cause and effect diagram, mapped the main problems that cause delays in supply and estimated that the work methods and environment cause 65% of the reasons for late orders. Exporting from ERP system all data for the year 2019, enabled usage of process mining, a massive analysis method, executed with DISCO software (by Fluxicon). While examining the prevalence of organizational actions and performance research focused on relevant parts of the process, map process analysis identified a gap between the desired and actual situation. The average time for order processing was 96 days compared to the 54- day factory standard. Economic calculations showed the costs incurred due to this delay caused logistics expenses of $9M a year. Therefore, research team focused on a goal to increase the on-time orders' rate supply by 8% (from 78% actual) and reduce logistics costs by 20% of the current situation.

In order to improve the delivery of on-time orders to customers, researchers employed several models. LEAN management method was utilized to improve the packaging process workflow. Using scheduling methods, EDD was selected as the most appropriate approach to minimize the late days and orders, as opposed to SPT, CR and the existing WSPT method. With the linear programing model, we determined the amount of facilities required for each type of packaging, and found that according to the annual capacity, an additional packaging facility was required for the 5-liter facility. This could be implemented by outsourcing or investment in purchasing. The weighted factor model, with criteria and weights chosen by company executives, implied that the best alternative is to add a packaging facility, for which the economic viability examination showed positive NPV with ROI of six months. All the results were applied to reach three main recommendations – changes in order scheduling, implementation of LEAN recommendations and purchase of a new packaging facility.

Based on this study, implementation of full recommendations will reduce the rate of late orders by 14%, increasing the supply measure to 98.6%. Adama Agan Ltd. will save $12.9M in logistics cost and thus overall logistics cost will be $21.1M. This is a reduction of 62% -- better than the target of 20%. This case used the methods in a distinctive way, so other companies with worldwide logistics can learn from it and improve complicated supply chain measures to reduce logistics costs.

This paper is organized as follows: Section 2 presents literature review, section 3 the research methodology, section 4 describes the case study, then section 5 discusses the results. Section 6 presents a discussion, section 7 outlines the conclusions, followed by the implications of the study and recommendations for further reserch.

2. Literature Background

2.1 Supply Chain Management

Supply chain management (SCM) is the management of the flow of goods and services and includes all processes that transform raw materials into final products. It involves the active streamlining of a business's supply-side activities to maximize customer value and gain a competitive advantage in the marketplace. SCM represents an effort by suppliers to develop and implement supply chains that are as efficient and economical as possible (Li, Ragu-Nathan, Ragu-Nathan, & Subba Rao, 2006). Supply chains cover everything from production, to product development, to the information systems needed to direct these undertakings. Another definition of SCM is systemic, strategic coordination of the traditional business functions and tactics across these businesses' functions within a particular organization and across businesses within the supply chain for the purposes of improving the long-term performance of the individual organizations and the supply chain as a whole. SCM has been defined to explicitly recognize the strategic nature of coordination between trading partners and to explain the dual purpose of SCM: to improve the performance of an individual organization, and to improve the performance of the whole supply chain. The goal of SCM is to integrate both information and material flows seamlessly across the supply chain as an effective competitive tool (I. J. Chen & Paulraj, 2004; Özge et al., 2019).

However, despite the increased attention paid to SCM, the literature has not been able to offer much by way of guidance to help the practice of SCM (Cigolini, Cozzi, & Perona, 2004), especially when dealing with global enterprises. Suggested improvement is based on the assumption that successful companies need to gain their cost advantage, value advantage or both (Christopher, 2016).

The purpose of this study is therefore to demonstrate how to identify problems on the supply chain of a global company and propose practical solutions employing IEM practices to create competitive advantage and organizational performance.

2.2 Process mining

As process mining is a relatively new discipline, some background is required. (Dumas, Aalst, Ter Hofstede, & John Wiley & Sons., 2005) discuss one of the most influential trends of the past decades: the shift from data-orientation to process orientation. The changing context stimulated the progression of process-aware information systems (PAISs) which can be found along the entire value chain: ERP (Enterprise Resource Planning), WfM (Workflow Management), CRM (Customer Resource Management), case handling, B2B (business To business) and SCM (Supply Chain Management) systems. Current study is focusing on SCM systems, although it is one global enterprise. Research was done considering the factory in Ashdod as a provider and the internal customers as clients.

Process Mining goes beyond the capabilities of traditional business intelligence tools (Golfarelli, Rizzi, & Cella, 2004) with respect to process analysis. Accordingly, as (De Weerdt, Schupp, Vanderloock, & Baesens, 2013) claim, it can be considered as a proficient means of assisting organizations to understand their actual manner of working, thereby serving as a foundation for process improvement. This is mainly since the cornerstone of Process

Mining is real data that demonstrates how business operations are carried out in an organization *de facto*. This is significantly different from other approaches to process improvement, such as interviews with key stakeholders or artifact collection.

Summarizing this definition at (van der Aalst et al., 2007) process mining is a relatively new discipline, based upon model-driven approaches and data mining. It proposes to provide methods, techniques and tools for the construction of models that adapt to concrete situations, examining system execution traces (i.e., logs). Although some Process Mining techniques have been proposed and a few tools are available, their usage still requires expertise in formal modeling and analysis. Therefore, they cannot be considered straightforward solutions. (Kedem-Yemini, Mamon, & Mashiah, 2018) presented vendors and tools comparison, for this research Disco (by Fluxicon) was selected. In this research the process mining enabled analysis of data collected at company's ERP system and provide semi-automated root cause analysis (W. Chen, 2016; van der Aalst, 2011)

3. Methodology

The research methodology included various methods, qualitative combined with quantitative. Data was collected by interviews, internal documentations, observations and from company's information systems. Various reports were scanned and analysed from the ERP system followed by the collection of data from the WMS system (Warehouse Management System).

In order to identify the problems, methods employed included forecasts, process simulation, LEAN management and Pareto analysis. Furthermore new methodology was used, process mining, with the PM2 framework (Kedem-Yemini et al., 2018; van Eck, Lu, Leemans, & van der Aalst, 2015). It enabled semi-automated root cause analysis. To complete this study team used scheduling methods, linear programing and economic feasibility.

4. Case Description

4.1 Adama Agan Ltd.

Adama Agan Ltd. is an Israeli company for crop protection materials that was founded in 1945 as a cooperative association of young chemists who graduated from the Hebrew University. Today it is one of the largest companies in the chemical industry in Israel. Adama manufacturers and retails herbicides, insecticides and fungicides. The company has research, development (R&D) and manufacturing facilities in various locations worldwide. It is traded on the Shenzhen Stock Exchange and is headquartered in Ashdod, Israel. Adama sells its products in approximately 100 countries through its 60 subsidiary companies around the world. The company mainly produces generic materials and as such is the largest in the world. The company employs about 800 employees, including agronomists, chemists and engineers. The plant produces dozens of active ingredients, processed into hundreds of formulations available for agricultural use. The production processes of the materials and preparations produced in the factory are the result of the R&D department's self-development. Agan's herbicides are sold in all countries of the world.

Our research focused on the supply chain management due to a delay in product deliveries that cause high logistics costs and sometimes sales losses. Since pesticides for agriculture are a seasonal product, it is necessary to deliver without delay otherwise the products will not arrive in time to the farmer. Any delay in supply can cause cancellation and loss of sales and so the problems we will address in this research are improving supply to customers around the world and reducing logistics costs for late payments.

4.2 Research Objectives

The main motivation was the high logistics costs summarizing to $34M per year (average based on 2017-2019 data) versus targeted $23M. The research goal set initially to reduce those costs. The initial study identified that the main cause would be the supply gap of 12% of late orders (from SLA of 10% allowance), which highly affects logistics costs. Therefore, second phase goal was to increase by at least 20% the on-time deliveries.

4.3 Data Collection

Data collection was done in 2 main phases. At the first phase research team collected data in qualitative tools according to (Yin, 2003). In this part interviews were done with key personnel at Adama Ltd. in various positions, observations were done on site and documents and artifacts were collected. Table 1 is summarizing the interviews phase. In the second phase quantitative data was collected – outputs of company ERP system and AWS systems.

Table 1. List of Interviews

Number	Role	Gender	Nu. Of Interviews
1	Logistics Manager	M	3
2	Production Manager	M	1
3	Planning Manager	M	2
4	Supply Chain Manager	M	2
5	Financial Manager	M	1
6	IT manager	F	1
7	Supply Chain Worker	F	2
8	Inventory Administrator	M	2

5. Results

5.1 Existing situation

After deep learning phase of the work processes in the organization, analysis focused on the customer supply process. This process starts at opening order and ends at exit from the factory gate. Examination was done on orders distribution, quantities, and type of packaging on data of years 2017-2019. A major gap found on the production/ packaging department, which includes three packaging lines: 1 liter, 5 liters, 10/20 liters. Figure 1 is presenting the distribution of supplied orders in years 2017-2019. It is clearly presenting the 64% increase in the weight of orders delivered and the 47% increase in the amount of orders in the 5-liter line (which is the most frequent) can be seen.

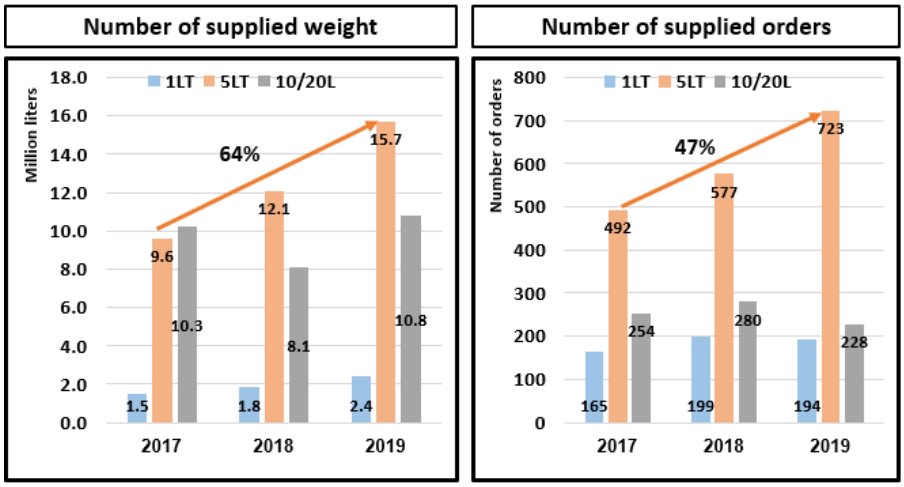

Figure 1- Distribution of Packing Facilities in 2017-2019

Summarizing the data in different way research team tried to point on the major problem that increased the logistics costs. Most of the cargo is sent to the customers by sea transportation, but due to last-minute problems some of the cargo is delivered by air transportation. Figure 2 shows the proportion of orders sent and it is clear that average of 17% of orders are sent by air transportation.

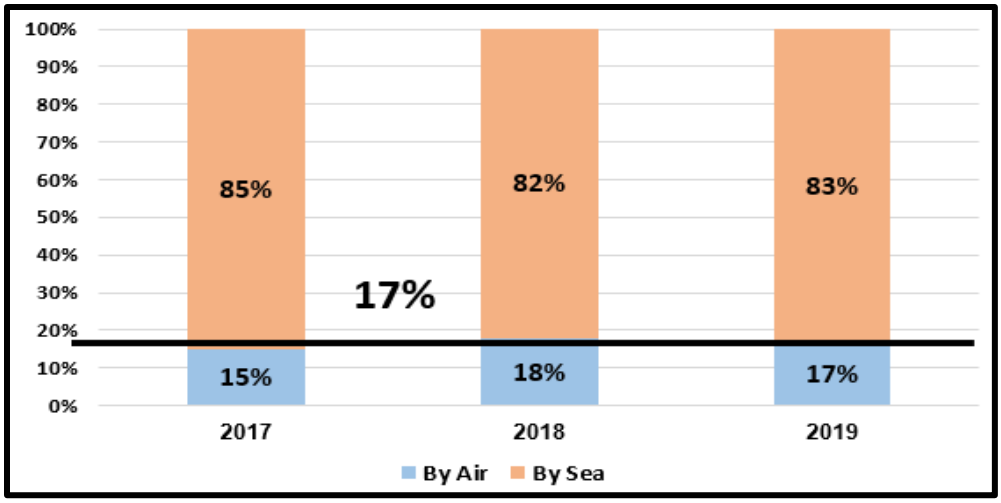

Figure 2- Distribution of Orders Sent by Air Transportation Due to Delays 2017-2019

The average annual logistics costs at Adama Ltd. Is presented in Figure 3. It is noted that the shipping costs during these years summarized to 25.3 M$, the costs of air shipments due to a delay were $1.7M and the costs of fines were $7.3M. This amount is 49% higher than the required logistics cost, which is 3% of annual sales cycle that is $780M.

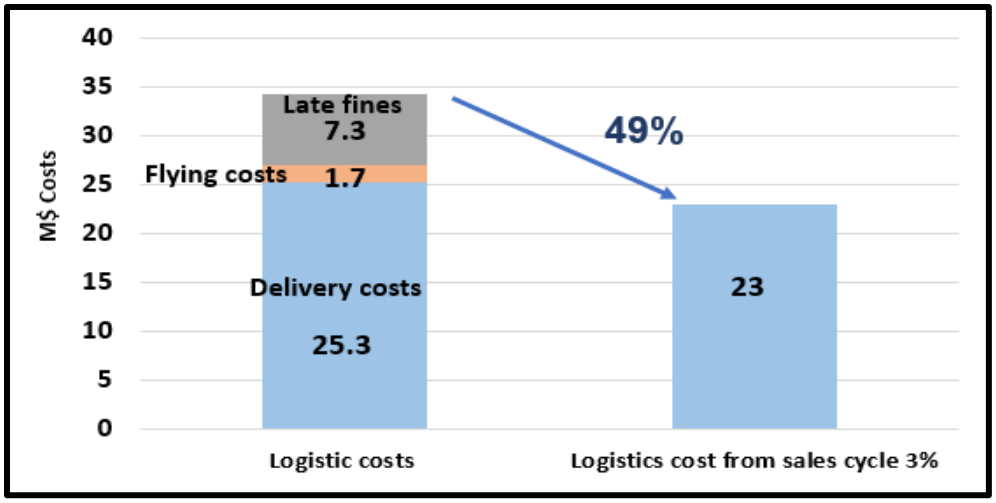

Figure 3- Average Annual Logistics Cost 2017-2019

The meaning of the data presented is the impact on the service level agreement (SLA) that the company is committed to provide. The goals are set by the company's management and the operational VP. While the target of 90% deliveries on time to customer, Adama provided only 78% of the orders on time while 22% arrived late to the customer. So, adding to the main goal of reduction of logistics cost a new goal, to reduce the 12% gap between the stated target versus the actual delivery.

5.2 Goals, Problems and Success Metrics

After presented analysis, a modification was done in the targets. Issues to handle set to:

1. 78% orders delivered on time versus a 90% target, a 12% gap.
2. $34M Average annual logistics costs, against a $23M organization goal, a 49% gap.

Therefore, research objectives and measures of success set to:

1. Increase on-time delivery from an average of 78% to 86%, at least 10%.
2. Reducing average logistics cost from $34M to $26M, at least 24%.

5.3 Root Cause Analysis

In order to identify exactly where are the problems research team utilized process mining for root cause analysis. All data gathered at the company's ERP system was mapped to work processes. Data of year 2019 exported by SQL query to external file and analyzed with Disco (by Fluxicon), one of the powerful tools for process mining. The procedure provided large amount of data (14,172 lines). Data was obtained to CSV file, handled with Excel. Before loading the data into the Disco, data optimization was done. 13,938 lines

Team created process maps that includes all the stages of the ordering process from the time of opening the order till the departure to customer. Figure 4 is presenting a summarizing view of process map, with target and actual times. In this chart the average duration of the treatment process is presented, found that ordering time is 96 days versus 54 required according to the company's objectives (the red color indicates the actual average processing time).

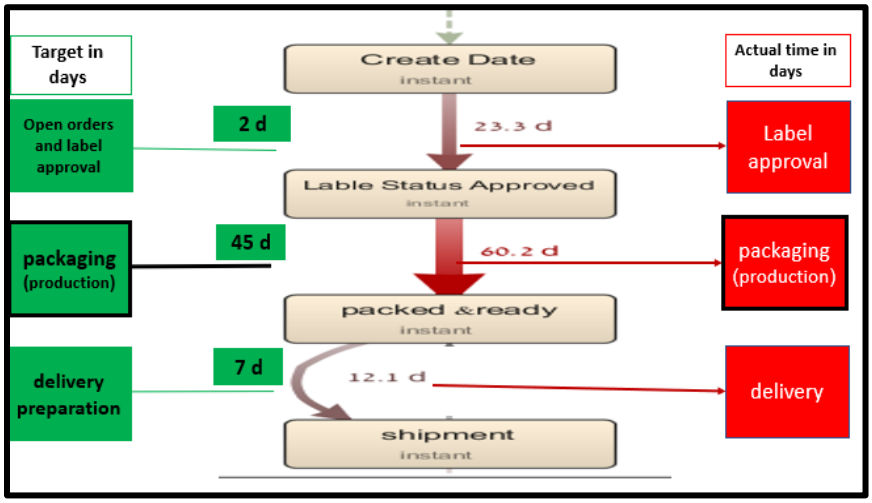

Figure 4- Process Map Chart in Existing Situation (2019 Data) as Analyzed with Disco

Figure 5 is presenting the orders process and it is clear that 885 orders departed on time to the customer with an average of 13.7 days before the requested delivery date, compared to 1,321 orders that departed with an average of 24 days after the requested delivery date. It is a result of company's work procedures - in the existing situation the team works according to the WSPT scheduling method because they give weight to each order according to customer priority by factors (such as size, order profitability, customer importance, urgency etc.).

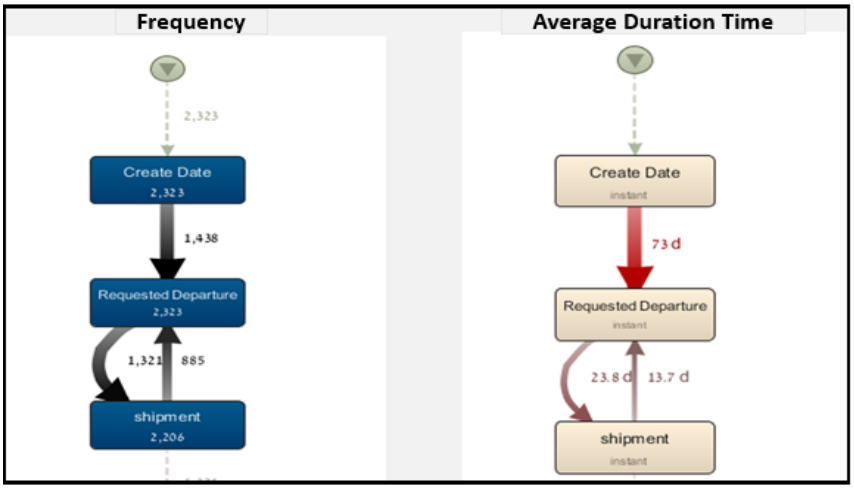

Figure 5- Mapping orders by the requested delivery date

5.4 Proposed Improvement

As process mining analysis led to the packaging facilities work procedure team used the data to simulate different scheduling methods. Focusing on 5 Liter facility (found to be the dominant in the department), divided to quarters (as company works today), a scheduling plan was prepared. Results are shown in Table 2, indicating that from four different schedule methods tested (current one plus 3 more) it was found that the EDD method while ordering the jobs according to the customer's arrival date is best for delivery times. According to this method, the average delay is between 0-1 days and the number of late orders is 32 (for year 2019 data).

Table 2- Scheduling Packaging in 5 LT Facility 2019

Scheduling method		**Current method-WSPT**		**EDD**		**SPT**		**CR**	
month	**Number of orders**	**Average delay-in days**	**Quantity of late orders**	**Average delay-in days**	**Quantity of late orders**	**Average delay-in days**	**Quantity of late orders**	**Average delay-in days**	**Quantity of late orders**
Jan. Q1	**50**	**0.2**	**11**	**0**	**0**	**0.5**	**26**	**0.2**	**12**
April Q2	**37**	**0.2**	**7**	**0**	**0**	**0.1**	**5**	**0.2**	**8**
July Q3	**53**	**0.3**	**15**	**0.4**	**20**	**0.3**	**15**	**0.3**	**18**
Oct. Q4	**53**	**0.8**	**40**	**0.2**	**12**	**0.1**	**8**	**0.4**	**23**

The LEAN management approach was employed to the packaging process. As this process is the bottleneck of the current supply chain any improvement can help reduce logistics costs and improve SLA. After obtaining approval from the plant engineer, team examined the packaging stages that do not add value to the customer and therefore can be reduced.

The results are that team offered a suggestion for the new process. It consists of modified stages, for example - shorten the stage of the sample inspection in the lab (before packing). In the existing state, the test time was 120 minutes. By preparing the laboratory ahead of time for the type of material which would be arriving, the test time was reduced. After this modification, this step will take 60 minutes.

Figure 6 summarizes the recommendations resulted by the LEAN management approach. It shortened the packaging process by 25% from 480 minutes to 360 minutes. The results are reflected in increasing the capacity to 33% from 12 tons to 16 tons of the facility. It of course will soon be reflected on target as increasing bottleneck facility capacity will reduce delays.

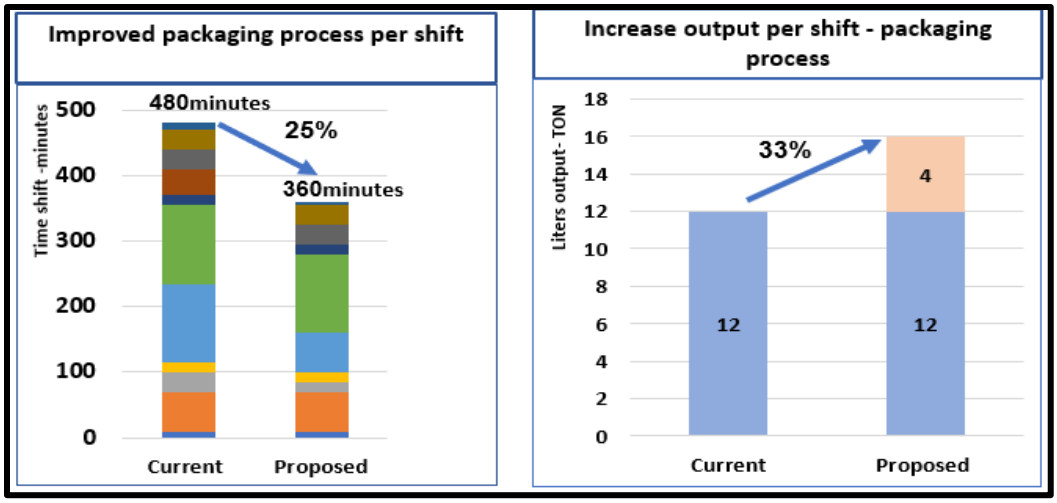

Figure 6 - LEAN Management Approach Summary of Improved Packing Process

In order to analyze the packaging facility holistically research team used linear programing. This method is providing optimal solution, and a model of all packaging facilities (1-Liter, 5-Liter and 10/20-Liter) was created with actual data and restrictions to estimate the required number of packaging facilities that will fulfill the company's needs.

The stages included problem definition, variables characterization according to the packaging facilities and the size of the tank and constraints. Evaluation was done to the annual production capacity for each facility versus the actual quantity sold. The model was solved with Lindo Software.

First run simulated the existing situation when there is only one facility in each production line. When examining the amount of facilities required to achieve the work plan, according to the Lindo output, there is a surplus of production capacity output on the 1-Liter and 10/20-Liter lines. However, for the 5-Liter line, it is required to open another line to reach requirements. The second run considered existing company's forecast sales plan in the 5-Liter line, which existing team recommended to perform. According to the Lindo output in this mode, the amount of facilities required is 3. Third run performed sensitivity analysis and considered reduced packaging time as per this research Lean's recommendations. This run showed that only the 5-Liter line did not achieve its work plan target and showed the need of one more facility.

Careful assessment was done according to those results. After clear verification that the number of facilities is not producing required capacity, team defined three possible alternatives to increase capacity: staying in the existing state, outsourcing packaging and adding a 5-Liter packaging facility. Those alternatives were examined with Weighted Factor Model (WFM) decision-making model with the company's management representatives to define the criteria, weight and grading. Customer satisfaction was defined as the most important criteria, and according to this model results adding a new 5-Liter facility is the best alternative.

Economic viability of the proposed investment was done. The duration of the facility usage time is 10 years, costing the machine depreciation of 10% of its value. NPV calculations with a capital price of 4.25% (current in Israel) will result on return on investment (ROI) within 6 months with NPV greater than zero. This indicates clearly that the investment is recommended.

6. Conclusion

The results of this implementing the research team full recommendation will provide two specific outcomes: reduction of logistics costs by 62% and an increase in annual packaging productivity by 340%. This is achieved with 4 layers. First, by LEAN management process, the implementation of the proposed process will reduce delays by increasing capacity per shift, thereby reducing logistics costs by $2.4M. Second, when packaging according to the EDD method of scheduling jobs, a drastic reduction in number of late orders will occur. Estimated per year 32 late orders, thus reducing costs by $7.5M, saving 83%. Third, since adding a packaging facility was the most profitable to the organization, the cost savings after implementing the model would be $3M which is a 33% savings. Finally, total logistics costs in the existing situation were $34M. After implementing the models, we were able to save $12.9M thus the proposed cost is $21.1M.

As per the SLA target, that was set to 86%, a dramatic change is expected there as well. After the implementation of the recommendations, we have 32 orders that are still delayed to customers out of 2323 orders that were shipped to customers a year. Therefore, it brings the company to reach an SLA of 98.6%.

In the total logistic costs, the target we set was $26M and after implementing all recommendations this offers total saving of $21.1M.

7. Discussion

Adama Agan Ltd. embraced the results and is implementing the recommendations on those days. Some of the recommendations, such as improved packaging process resulted by Lean analysis can be implemented within short time, while some others, such as purchasing new 5-Liter facility, it is long term solution.

Another implication of this research is the use of process mining tools in the company, in order to evaluate other processes. This technology is relatively new and can create substantial advantage to enterprise company. The company has an ERP system; therefore, data is gathered bat the ability to analyze process is not possible without appropriate tool. Final implication was establishment of relationship between Academia to Industry. Adama Ltd. is a global enterprise located in the southern of Israel. This research was a good start to establish solid connection between this company and Sapir Academic College, located as well in this area. Those relationship provide valuable recommendations to industry while provide students the opportunity to internship, with professional mentoring. Through this kind research Sapir Academic College is providing Logistic students this opportunity.

8. Limitations and Future Research

Case study research from its nature has advantages and limitations. Case study strengths are that they can help us understand complex inter-relationships, are grounded in live-events, and can demonstrate easily implementation of models. Though, presented limitations are that the complexity examined is difficult to represent simply, it is hard to generalize from one case and the "objectivity" can be problematic (Aberdeen, 2013; Yazan, 2015; Yin, 2003). However, this case can be used to demonstrate the unique use of process mining tool for root cause analysis, it demonstrate how research goal are changed during the information gathering stage and how to estimate on real data IEM methods.

Further research is required in two main levels. The first, local, is to assess the implementation of full recommendations on Adama Agan Ltd. and to estimate if packaging facility capacity has influenced as estimated. The second level is theoretical, that will ask the question can researchers develop a tool to indicate logistics gap in supply chain delivery and can offer a model to handle such gap? This theoretical analysis will have a major contribution to logistics chain analysis.

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Biography

Ortal Biton: A student for bachelor's degree in the Logistics Department at Sapir Academic College, works at Adama Agan LTD. as a logistic coordinator. Ortal's responsibility includes the logistics process in the organization from the arrival of the raw materials to the plant till the exit as a final product for customers.

Sagit Kedem-Yemini is an Industrial Engineer, proficient in information systems and currently holding two lecturing positions: a tenured lecturer position at Sapir Academic College (Logistics Department) and an adjunct lecturer at Ben Gurion University (both in IE&M and Faculty of Business and Management). Her teaching portfolio is broad, focusing on Enterprise Systems implementation (SAP and Oracle Applications) and derivatives of ERP data collection – from Business Analytics to Process Mining. Additionally, she has extensive experience in academic curriculum development, is head of her department's teaching committee and serves as liaison to the graduation projects unit. Her research interests include Process Mining and its practical applications, ERP relates issues and DSS development. Since 2015 serves as member of JITCAR Editorial Review Board.
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Tamar Navon is a senior consultant at Omega Consulting and serves as Student facilitator at Sapir Academic College in Israel, in the departments of Logistics and Industrial Management. Mrs. Navon holds a Bachelor of Science degree in Industrial Engineering from Tel Aviv University and a degree of System Analyst from Sivan College. She has worked as a professional management consultant to organizations in various sectors, manager of several departments in the IT business with over 25 years of experience.