Optimizing Inventory Control in A Microbiology Laboratory to Provide High Quality Patient Results

Kemlall R. Ramdass
Professor of Industrial Engineering
Department of Industrial Engineering
University of South Africa ,Roodeport, South Africa
ramdakr@unisa.ac.za

Mulde van der Wateren
Student of Industrial Engineering
Department of Industrial Engineering
University of South Africa, Roodeport, South Africa
33076472@mylife.unisa.ac.za

Bongumenzi T Mncwango
Lecturer of Industrial Engineering
Department of Industrial Engineering
Durban University of Technology, Durban, South Africa
bongumenzim@dut.ac.za

Abstract

The measurement for quality in a clinical laboratory is to deliver reliable patient results within a specific time frame. To do so, it always needs sufficient stock levels. Unfortunately, little attention is given to inventory management and a designated laboratory worker is assigned to do inventory management tasks. In order to optimize inventory management, principles should be implemented to plan for future demands, buffer for present stock shortage, eliminate obsolete stock and modernize the system to ease follow ups on orders and back orders for all relevant staff. An experimental approach was used where known principles and methods were applied to determine if the outcome would add value. Interviews with staff, historical data, and observations in terms of time and money were statistically analyzed. It was concluded that all principles, including modifying safety stock were valuable in optimizing inventory management. The amount of safety stock to carry should be determined by the balance between cost and services needed. The principles should be extended to the entire inventory and real-time receiving should be investigated and implemented for added improvement

Keywords
ABC Analysis, DMAIC, Optimization, Inventory Control, Demand Forecast

Introduction
In the laboratory environment, a designated laboratory worker is responsible for inventory management in addition to routine laboratory tasks. Inventory control in this particular laboratory has been very old fashioned, with no other formal training for materials management officers than using the company software to place orders, receive and issue stock. It is also difficult for managers and helpers to solve queries regarding outstanding orders, back orders, and stock levels. This issue, results in duplicate orders and a delay in following up on outstanding orders, because of the current system being on paper file. The responsible person is not always available to handle queries. Implementing an online document system could ease problem solving in terms of outstanding orders and stock on hand, as well as utilizing software available to improve time spend on inventory control.

In the past, inventory management was roughly based on the Just-in-time models, with order size being determined by current demand. Regular stockouts occurred, resulting in workflow interruptions, purchasing of alternative items at excessive costs and occasional overstocking. The biggest challenge in a clinical setting, is that demands fluctuate according to season as well as day-to-day. It makes it overly complicated to ensure sufficient stock levels, especially during disease outbreaks. It is suggested to keep a month's supply however, spacing is a problem. Implementing ABC analysis which categories inventory items according to the principle of the expensive few, facilitate strict management of items that has significant impact on the laboratory's expenditure. Realtime issue of stock items used, would decrease time spend on counting of stock and reduce duplicate orders. In order to prevent stock outs that result in delay in release of patient results, monetary loss or overstocking, the inventory management system needs to be optimized. Efficient inventory management results in cost reduction by eliminating excess stock from the inventory, maximizing production and produce high quality service. High quality clinical services decrease hospital patients' length of stay, it provides valuable diagnosis for treatment information for outpatients and ultimately save lives.

The company consists of different departments doing different type of tests. The microbiology department deals with pathogens causing disease in humans. This particular laboratory is centralized as a national reference laboratory for South Africa in this particular company. If any outside branch has stock issues, specimens are forwarded to this branch. It gets on average 16 800 urine samples, 2400 stool samples, 3360 sputum samples, 2400 tissue samples, as well as surveillance samples and other miscellaneous samples a month. Optimum inventory management with such a workload is crucial for the department to be profitable. The disease outbreaks can lead to a sudden increase of a specific specimen type and puts pressure on the given resources. The Listeria-outbreak has contributed to a sudden increase in stool specimens, average 5000 samples a day. It is impossible to plan for such outbreaks, but it is important to adjust inventory needs immediately and act accordingly. Unfortunately, it can also have the opposite effect, for instance with the Salmonella-outbreak that was in the media, beginning of the year, efforts were put into ensuring enough reagents for Salmonella testing and overstocking occurred, because the outbreak was limited. The laboratory staff work in shifts to manage the workload and it is a high-pressure work environment, since you have to complete test procedures within an allocated timeframe, without taking workload into account. Attention to patient name, test requested, and other clinical detail should not be neglected disregarding if you have 2 or 20 tests to do. These circumstances contribute to their resistance against getting involved in stock management and most are trained scientists with little interest in the business aspects of the department.

Objectives

The aim of this study is to increase clinical services by optimization of inventory management, therefore always ensuring sufficient stock levels, reduce stock wastage and involve staff members with the process.

The objectives include:

Facilitation and implementation of inventory optimization actions to always ensure sufficient stock levels available.
Introduction of quality control systems to prevent stock wastage.
Involvement of staff members in optimization of inventory management.

Literature Review

A limited amount of literature is available on inventory management in clinical laboratories, which emphasizes the issue that inventory and supply chain management does not get much attention in the health care environment, although 15-40% of total expenses in clinical laboratories is tied up in stock (Alsalameh and Ababeneh 2018).The value of clinical service is defined by turnaround time for an accurate result (Beheshti et al. 2012). The turnaround time is the time elapsed from the medical specimen enters the laboratory until a final result is send to the doctor or patient. In a clinical setting, inventory consists of perishable items, disposable items, and non-disposable items (Bijvank and Vis 2011). Moreover, the perishable items tend to complicate the inventory supply system, because operations cannot continue without them, but if you overstock, it might expire, which leads to financial losses.
Biijvank and Vis (2011) investigated this phenomenon in terms of drug supplies in hospitals.

According to O'Mahony et al. (2021), overstocking also occur in addition to the fear for stock outs and the significant complications it creates on patient care. Having items in multiple locations can contribute to overstocking, although it is a natural instinct of fear for running out or not having the items available when needed (O'Mahony et al. 2021). Pandey and Raut (2016), stated that quality control methods can be used to prevent stock wastage by packing items that were received first in front for staff to utilize it first. It is naturally assumed that suppliers sent stock with the shortest expiry date first. FIFO (First-in-First-out) is actually a quality control system that is used for inventory valuation, but it is also an excellent system to prevent inventory items to expire, because the newest items are packed behind the old items. Suppliers sent stock with the shortest expiry date first. In this way stock can also be packed on top of each other and space can be utilized more effectively (Pandey and Raut 2016).

In spaces where storage spaces available is limited, Bijvank and Vis (2011) emphasized that the space available should be used efficiently and a balance between optimum stock levels and customer service should be found by means of a service model in hospitals. I think this theory can be extended to clinical laboratories as well, because space is also limited and monthly ordering for bulk supply is not feasible. Priyan and Uthayakumar (2014) proposed a model to produce effective management of pharmaceuticals to ensure the 100% product availability at the right time, at the right cost, in good condition to right customers. ABC analysis was proposed to be a helpful strategy in health care facilities by Beheshti et al. (2012). Just-in-time principle for inventory management indicated to be not as effective, because of the unpredicted demand in the industry.

According to Shukran et al. (2017), a need for developing a centralized, automated system to enhance productivity and efficiency in a chemistry laboratory emerged with an increase of capacity. In their study QR codes were used but the technology available in this study is too old fashioned for QR codes, therefore barcodes are going to be implemented. Another means of automation to address the manual inventory system is to implement a digital solution. Six sigma was used with a person-centered approach in order to get a solution that is specific for the problem, it also motivated staff members to engaged with the system (Wolfe et al. 2021). This is exactly what the aim for the change is, to create a user-friendly system to keep up to date with stock order, especially for staff members that is more clinically orientated, like clinicians (Wolfe et al. 2021).

Six sigma is a methodology for improvement and a concept that seeks to define the variation inherent in any process (The council of Six Sigma 2018). The argument is that if a process has variations, it makes it error prone and six sigma try to prevent these errors from happening. It can also be applied to any industry or process. Since the inventory management system in the microbiology laboratory is so old fashioned, it was decided on six sigma for the document system, because it is going to be an ongoing process for improvement and modernization. The difference between a hospital setting and a clinical laboratory, is that the task in a laboratory simulates a production line, with more emphasis on completion of tests, where hospitals are more patient orientated. The stock demand fluctuates in both settings.

1. Methods

A root cause analysis was done by means of an Ishikawa diagram. Managers, staff, and suppliers were interviewed, and causes were determined. Only staff working with stock and orders were included. The quantitative data were used to determine the worthiest cause for the stock issues experienced. Workflow was not to be influenced by the project, so it was decided to use a secluded bench as workstation and stock used there would be included in the project. It is easy to train staff and prevent external factors to influence findings because it is isolated.

ABC Analysis were done on all stock items in the inventory, by calculating stock item's percentage contributing to the total annual expenditure. Items contributing 75% were categorized as A category.
Two items were picked from this category, according to the following criteria.

a. The cost should be significant in terms of expenditure (ABC analysis).
b. It should present daily stock usage
c. It should be perishable
d. It should not be influenced by disease outbreak.
e. It should not be influenced by seasonal fluctuations
f. It should be used on this workstation.

Historical data was collected for kit A and B to determine usage, forecasting, re-order point and safety stock. Monthly average was calculated by taking the annual usage and divide it by 12. The weekly average was calculated by dividing the monthly average by seven, all answers were rounded off.

Tests ordered were converted to number of tests ordered in comparison to number of tests done. Kit A is packaged as 20 tests per box and kit B 25 tests per box. Over stocking and under stocking could be determined, as well as usage of alternative suppliers.

Safety stock were calculated with the formula:

Safety stock= [Maximum daily use x Maximum lead time]- [Average daily use x Average Lead time]

It turned out to be not economical feasible and revised to:

Safety Stock = (Annual Demand/365) x (Number of days you need stock).

The costs of stock outs, using alternative suppliers and keeping safety stock on hand was calculated and interpreted according to percentage cost saved or lost. Safety stock was calculated by multiplying the cost of one kit with the amount of kits on hand. Cost of alternative kits was also multiplied by the amount and number of kits used and then subtracted by the cost of normal usage. The difference was divided by the normal usage to get a percentage. Costs of stock outs were calculated by multiply the cost per test by the amount of tests that could not be done, this was subtracted by the income if the tests were done. This amount was divided by the income of tests that would have been done to get a percentage.

Months with no stock outs or alternative suppliers were excluded from the calculations because the inventory management principles would not contribute value to it. To Implement FIFO (First-in-First-out) upon receival all kits were marked with a bright green colored sticker, indicating the received date. The staff member allocated to unpacking stock, were responsible for marking the kits and pack the new stock at the back of the shelf in the fridge. The oldest kits would be used first to prevent expiry. The automated issuing was introduced as follows;

i. Barcodes with the item number was available on the bench at the workstation with all other information needed in order to issue it on the system when a kit is opened.
ii. Bar code scanners were available next to the computer at the workstation to assist in ease of use and time management. The automated issuing was only implemented with the usage of kit A and B. A bar code scanner is used to scan the numbers, which makes it quick and efficient. Every time a kit is taken out of the fridge and put in use on the particular workstation, it needs to be issued.

The time study was used to determine the time spend on tasks such as stock count, placing orders and stock issues. The tasks measured were repetitive and done on a weekly basis, which was perfect for time study. It was timed with a stopwatch and the time observations before automation and after automation were compared. The time after were subtracted from the time before automation. The difference was divided by the original task times and expressed as percentage. Only time spend on stock count in the freezer (kit A and B storage) and time spend on issue were included, because automation of issuing would not have any influence on the rest of the tasks. The tasks of the time study were divided in printing of inventory list, stock count in the storeroom, stock count in the media room, stationary count, stock count in the stool bench, stock count in the fridge, stock count in the freezer, stock order and stock issue.
The DMAIC process were conducted as follow:

Defining the problems:
Orders are created on the Meditech system
A hard copy is printed and filed in an Orders file
Follow up by materials management officer
Emails are sent to suppliers after normal lead (7 days) time is exceeded
If there is a stock out, suppliers are contacted for emergency delivery
or alternative supply is located
The materials management officer has a specific user screen that managers do not have
The materials management helper has access to the user screen but are not always up to date with weekly orders.
When the materials management officer is not available, they do not have access to the office where the file is held.

Define the problem: Managers and materials management helper needs access to orders placed and items on back-order.

Measuring: Because the materials management officer has laboratory tasks as well, orders are not received real-time, neither is it unpacked immediately upon receival. When stock items are not available on the workbenches it is most of the time in the laboratory, but still unpacked. Duplicate orders are placed by the materials management helper because they are not aware of other purchase orders placed. Managers must phone the materials management officer to find out what is going on. (Laboratory staff work different shifts).

Analyze: The File system is not working to aid transparency of stock issues. The material management helper cannot assist with all orders, because of different shifts and laboratory tasks. Stock enquiries was needed about once a week, depending on the amount of stock received and the staff available for laboratory tasks. There is not a specific trend in enquiries.

Improve: An online solution was suggested. The materials management officer could send a copy of the orders placed and present back orders to all relevant staff. It is a labor-intensive task, because the list of orders placed should be downloaded and copied into an excel sheet. The back orders must be typed. The solution decided on was to import the list of orders placed directly on a google spread sheet, where real-time edits can be done. The back orders are copied on another spread sheet and comments on estimated time of arrival and date of follow ups are entered. The sheet is simply shared with the relevant staff. In this way typing errors can also be avoided.

Control: The google sheet should be updated as changes occur, otherwise it is going to be outdated and not a real reflection of stock available. Relevant staff members should view the sheet regularly to stay informed.
The google spreadsheet with the week's back orders and orders was created to be available for all employee's involved in stock queries. After the action plan was implemented, it should be controlled to make sure that the original problem does not come back. The materials management Officer would be responsible for keeping the spreadsheet up to date and following op on back orders.

2. Data and Collection Methods

ABC analysis was used to analyze quantitative data by categorizing items according to their proportion of annual value to the overall annual value of the inventory. The items with the highest monetary value can then be identified properly for use in the project. Historical data was retrieved from the company's inventory management system for the past year and used to determine forecasting, re-order point and safety stock. The data collected was evaluated by the number of days on hands of the items before and after implementation, time used to do inventory tasks like stock count, issue and orders and comparison of monetary value of safety stock on hold, cost of stock outs and costs of using an alternative supplier if issues are encountered with the current supplier. Six Sigma's DMAIC approach is to be used to implement and evaluate the online orders and back-order status system.

3. Results and Discussion

4.1 Ishikawa Diagram

The Ishikawa diagram were created, and it was confirmed that poor inventory management was one of the reasons why stock outs occurred, in conjunction with supplying issues of suppliers and lack of motivation of personnel to get involved. It could be measured in terms of stock not being available to do tests, overstocking was detected on high days on hands figures and costs involved in annual expired stock.

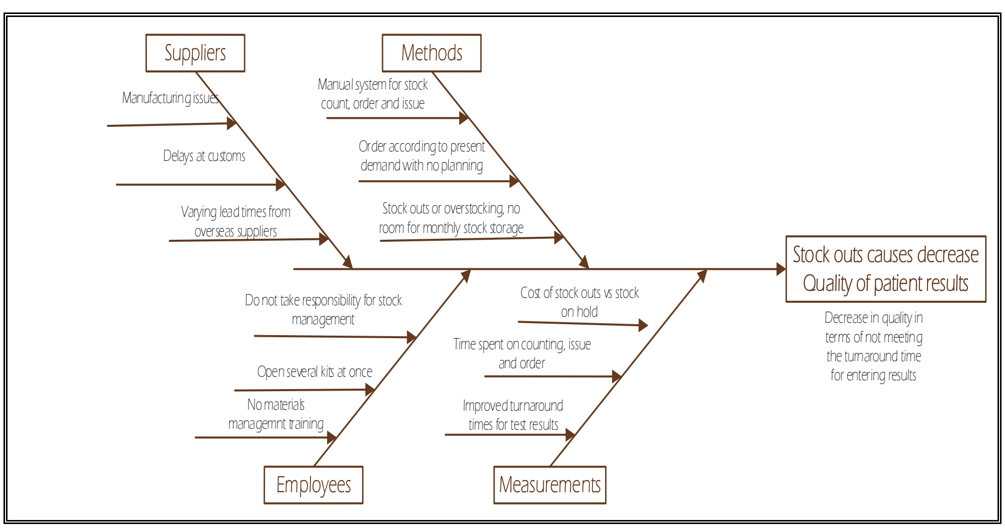

Fig 1. Ishikawa diagram of causes of stock outs and decrease in quality of patient results

3.1. ABC-Analysis

ABC analysis identified kit A and B as category A items, the critical few Heizer & Render (2013), that have a significant impact on monthly expenditure.

Demand forecasting, re-order point and safety stock

In table 1 the data collected for kit A is displayed. Months where alternative kits were used are highlighted in green. Usage per month varied between 54 and 50 and in conjunction the weekly usage varied between 12 and 14 (Table 1). Surprisingly, the receipt and issue did not correspond.

KIT A

Table 1. Kit A usage

Year	**2019**		**2020**		**2021**		**2022**	
Month	**May**	**June**	**May**	**June**	**May**	**June**	**May**	**June**
Receipt	65 (alternative supplier)	60	45 (Alternative Supplier)	30	45	45	105	118
Issue	0	120	40	4	69	36	76	126
Days on Hand	10	15	20	20	16	16	14	10
Usage per month	52	52	54	54	50	50	52	52
Usage per week (7 days)	13	13	14	14	12	12	13	13
Lead time (Working days)	3-5 days	3-5 days	5-7 days	5-7 days	3-10 days	3-10 days	3-5 days	3-5 days
Cost of safety stock revised	R3859.92	R3859.92	R3859.92	R3859.92	R3859.92	R3859.92	R3859.92	R3859.92
Cost pf alternative stock	R49 543-65		R34 299-45					
Cost of stock out				R28 016-50	R39 264-00			
Tests ordered	1300	1200	900	600	900	900	2100	2360
Tests done	498	878	755	737	1092	538	1140	2097
Difference	802	322	145	-137	-192	362	960	263

The lead time increased during the Covid period to a maximum of 10 days and decrease again to a maximum of 5 days. The variation in lead times can also be seen during Covid it was anything between 3 and 10 days, which impact the number of safety stock significantly. The days on hand was at its highest during 2020 and it decreased to the target of 10 days during June 2022.

The tests ordered were compared to the tests done in the laboratory. Kit A is packaged as 20 tests per unit ordered. According to the calculations it is evident that overstocking occurred in May 2019, with excess of 802 tests and May 2022 with excess of 960. Stockouts occurred in June 2020 with 137 tests that could not be done and May 2021 where 192 tests could not be done. The cost for keeping 30 kits of safety stock for kit A would be R19 299-60. It was decided that it is not economically feasible, and the formula was revised to using three days stock based on average annual usage. The cost for safety stock on hold was R3859-92. Cost of stock outs were R28 016-50 in June 2020 and R39 264-00 in May 2021, respectively. Purchasing alternative stock in May 2019 had a total cost of R49 543-65 and in May 2020 it was R34 299-45.

KIT B

As indicated in table 2, monthly usage of kit B was between 7 and 20, with a sharp increase in usage since 2021. Weekly usage was between 2 and 5. Stock outs are highlighted in green for June 2019 and May 2021, where an alternative supplier was utilized. The receipt and issue of kit B was within closer range. The lead time had the same variation as mentioned previously with kit A. The days on hand as indicated in Table 2 varied from 9 to 20. The highest days on hand were also 2020 and 2021 with a definite decrease to 9 for June 2022. The target is 10. Lastly the number of tests ordered were compared to the tests done in the laboratory. The packaging of kit B was 25 tests per unit ordered.

Overstocking occurred in May 2021with excess of 523 tests and stock outs were indicated in green at the bottom of the bar in May 2020 where 63 tests could not be done and May 2021 where 9 tests could not be done. The cost for keeping a monthly safety stock of Kit B is R22 696-11. As mentioned above, the formula was revised, and cot of safety stock was calculated to be R7565-37. Stock outs in May 2020 was R44 622-90 and R6374-70 in May 2021, where purchasing of alternative stock when it was available in May 2019 costed R39 853-80 and R33 211-50 in May 2021.

Table 2. Kit B usage

Year	**2019**		**2020**			**2021**		**2022**	
Month	**May**	**June**	**May**	**June**		**May**	**June**	**May**	**June**
Receipt	9	12 (Alternative supplier)	3	9		10 (Alternative supplier)	16	32	14
Issue	10	18	7	6		16	6	25	11
Days on Hand	10	15	18	20		13	17	11	9
Usage per month	7	7	9	9		12	12	20	20
Usage per week (7 days)	2	2	2	2		3	3	5	5
Lead time (Working days)	3-5 days	3-5 days	5-7 days	5-7 days		3-10 days	3-10 days	3-5 days	3-5 days
Cost of safety stock revised	R7565-37	R7565-37	R7565-37	R7565-37		R7565-37	R7565-37	R7565-37	R7565-3
Cost pf alternative stock	R39 853-80					R33 211-50			
Cost of stock out			R44 622-90			R6 374-70			
Tests ordered	225	300	75	225		250	400	800	350
Tests done	130	167	138	144		259	213	277	293
Difference	95	133	-63	81		-9	187	523	57

3.2. FIFO (First in-First out)

An estimated 1% of Kit's annual usage is lost because of obsolete stock that expired. That would be a loss of R14 796.36 for kit A and R5043.58 for kit B per annum. Ideally FIFO would result in a zero monetary loss due to expired stock after implementation.

3.3. Time Study

The time study showed that average time spend on stock count in the fridge before automated issue, is 41 min. The kits are stored in the fridge. The average time for issue is 42 min. After automated issuing were implemented, the average time spend on stock count in the fridge went down to 38 minutes, which shows a 7.3% decrease in time spend on the task and the average time spend on issue went down to 40 minutes. The time spend on issue showed 5% decrease.

4.4 Digitalization of Orders

The weekly orders were presented on a Google spread sheet. The purchasing department, the item, number of items ordered, and supplier name were visible on the orders sheet. Expected lead time was a maximum of 7 workdays. Back orders were also shared on a weekly basis with relevant staff and updated as changes occurred. Back orders that were delivered were removed. Additional back orders were added. If an order were partially delivered, the outstanding items would be considered as a back order or if the lead time exceeds 7 workdays. Notes were added on stock level available, and action taken where deliveries were still outstanding. "Stock low" was used to indicate concern about stock levels and required close monitoring to prevent stock outs. Monitoring should be to follow up with the supplier for a delivery date or getting an alternative supplier in line.

4. Discussion

The receipt and issue for kit A did not correlate. It could be because receiving is done on the Meditech system according to time available and not according to real time receiving. Stock items are issued on a weekly basis and that can contribute to difference in stock received versus stock issued. Kit B did not have much variation in issue and receipt, and it could be because a smaller number of kits are being used. It is always easier to manage smaller numbers of items well. The results showed that the difference in receiving and issuing decreases significantly in July 2022 after real time issuing is implemented [11]. It implicates that the real time issuing assists with a more effective inventory management where the amount of stock items ordered, are being used. No stock outs occurred during June 2022 for both kits A and B. According to the historical data, the stock outs did not occur on a monthly basis, so the fact that no stock outs occurred in June could also be luck and not necessarily skill. The peak in days on hand in 2020 and 2021 could be caused by the unpredictability of lead times due to borders closing and opening without any notice as well as production challenges. Overstocking was a way to ensure sufficient stock available in the laboratory for both kit A and B during Covid. The goal days on hand for this laboratory is 10. The flattening of the curve in June might be due to the inventory management principles (forecasting, re-order point and real-time issuing) that were introduced and followed.

The cost of total stock out or use of alternative suppliers is directly related to the time that it occurs. The more days without stock, the more kits are needed and the more money it costs. This is especially evident with kit B in May 2020 and May 2021. Surprisingly, safety stock would not necessarily save money. The holding cost of 30 kits safety stock of kit A would cost 18% more than using the alternative stock with the supply issues in 2019 and 2020. Holding cost of kit B safety stock would be 32% more than using alternative stock. If no alternative suppliers are available, safety stock would save the day. In kit A's case safety stock would have saved between 31% and 51% of losses due to tests dot being done and in kit B's case it would have saved 49% in May 2021, but it was 32% more expensive to keep safety stock. These findings highlight the need for having safety stock available. But emphasis is on the right amount of safety stock. According to the findings it can be derived that the incorrect safety stock formula was used to calculate the safety stock. Keeping too much safety stock in future can be a safety belt in order to not implement and keep good inventory management principles in place [26]. It is suggested to keep less safety stock on hand, for instance stock for only 3 days, in order to get stock from the alternative supplier. A good client-supplier relationship is needed for this arrangement.

With an annual loss of 1% expired stock, FIFO would assist in prevention of financial losses, but staff responsibility is emphasized in ensuring that stock is rotated on the shelf according to date received. If the stock items with the shortest expiry date are packed in front and used first, it would ensure that all stock are used before expiry. As suggested by Shukran et al [11] the automated real time issuing speed up stock counting in the fridge by 7.3% and issuing were 5% quicker, which gives the materials management officer a total of 12.3% more time a week to spend on laboratory tasks.

All relevant staff were informed about the google sheet with back orders and weekly orders and they were satisfied with the ease of access, since all of them must check in on emails at least once a day. It also improved communication between managers, the materials management helper, and the materials management officer. When they saw back orders or low-level stock, they would make an enquiry in person. Therefore, stock management were improved as well, because they would make suggestions on alternative stock sources, modifying tests procedure to conserve stock resources or communicate with suppliers on a higher level in order to expedite deliveries where appropriate.

These findings suggests that forecasting and re-order point increase effective stock management and real time issue by means of automation decrease time spend on materials management tasks. Transparency of the inventory system results in a more hands on approach by staff.

Green engineering should be kept in mind with every new system or method implemented, in order to preserve resources and protect the environment. Optimizing of inventory management result in an overall reduction of generating waste. The biohazardous waste, which is the reagent kit itself is demolished by a regulated medical waste system. The waste is incinerated and if the volume is reduced, it means less air pollution is produced. A recycle bin is provided for the packaging and a biological hazardous bin is provided for the biological waste. The implementation of the online system prevents usage of paper for the inventory system, and it also aids in preservation of wood resources. The specimen containers in use are locally produced, but unfortunately it ends up in the biological waste, since it is biohazardous. Energy usages are reduced by having an alarm in the fridge that goes off if the fridge door is open for too long and the temperature increases, and the filter are cleaned regularly in order for it to function properly. The laboratory building has solar panels installed on the roof to reduce electricity usage.

5. Conclusion and Recommendations

The correlation between receipt and issue as well as a decrease in days on hands in the last month of observations suggests that the implementation of forecasting and re-order point increase effective inventory management. FIFO is an effective quality control method for inventory management where perishable goods are concerned and it aids in general housekeeping by allowing one to store kits on top of each other and behind each other that results in more effective space utilization.

Safety stock should be reduced, in order to be cost effective, but it would still save money with stock outs. Alternative suppliers for kit A and kit B are more feasible in times of supply shortage in comparison with keeping a high number of safety stock on hand. If the safety stock is calculated correctly, it is most of the time more cost effective to have safety stock on hand. Realtime automated issuing proofed to be very successful to assist with stock forecasting, as well as decrease time spend on tasks like stock counts and issue. It is recommended to explore the possibility of real-time receiving to free more time for the materials management officer as well as assisting with more efficient stock control. It would also further involve laboratory staff in inventory management tasks. Transparency in the inventory management system promote collaboration between staff and management for optimal control.

As mentioned in the methodology, the study was only conducted with a limited amount of space and resources. It is recommended to include more stock items with the aim to have forecasting, re-order point and real-time issue for all inventory items where possible. Revised safety stock should be kept for all category A items, category B items and category C items should be allocated safety stock items on discretion of management and the materials management officer. The decision should be made according to the organization's objective in terms of a balance between cost and service level. If alternative suppliers are sourced, preference should be given to green companies that use recycled products or agents that is environmentally friendly to conserve resources for sustainability. In order to see if the principles implemented are successful for preventing stock outs, a longer time of observation is recommended.

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Biographies

Prof Kem Ramdass has worked as a work-study officer, industrial engineer, production/operations manager and skills development facilitator in the clothing, electronics, and textile industries between 1981 and 1999. He joined the academic profession in 1999 as a lecturer with Technikon South Africa. He later moved to UNISA’S Department of Business Management in 2006 lecturing in operations management. He is currently a Professor in the Department of Industrial Engineering based as Unisa, Florida Campus. He has a passion for quality and firmly believes that the application of quality management methodologies will highlight deficiencies and instigate the implementation of improvement strategies. He has applied continuous improvement methodologies from an industrial engineering, quality, and operations management perspective. He is a process, performance, and operations specialist with a driving passion for improving production, quality, and competitiveness. He has authored and presented approximately 50 journal and conference papers both nationally and internationally and is a peer reviewer for numerous publications. He has achieved Fellow member status at SAIIE and is a member of PICMET and IEEE. He is registered as Pr Tech Eng at ECSA and is appointed as a member of the Code of Practice Steering at ECSA.
Mulde van der Wateren is an Advanced Diploma student at the Department of Industrial Engineering at UNISA

Bongumenzi Mncwango is currently completing his PhD. He obtained his BTech in Industrial Engineering from the Durban University of Technology and MSc in Management and Optimization of Supply Chains and Transport from Ecole des Mines de Nantes, France. He is a member of the Southern African Institute of Industrial Engineering (SAIIE). He enjoys lecturing and interacting with students in all levels of study.