A Modular System Deploying a Natural Processing Language and Lean Six Sigma (LSS) for Efficient Complaint Resolution System – A Case Study of Pakistan Citizen Portal (PCP)

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Abstract- There is an inherent quality of greed in nature of human beings that makes them ask for more. Be it a product or a service, the list of expectations by human beings is less likely to subside rather it continues to grow. To keep up with these growing expectations, industries need to take nonstop feedback from their customers or clients. Then, they work on their product or service in light of that feedback and thus enable themselves to not only keep their customer base intact but also increase it. There are many feedback taking systems around the world. One such system is the Pakistan Citizen Portal (PCP) that is operated on governmental level in Pakistan. The PCP is a complaint resolution system that receives complaints from the general public regarding their interaction and experiences in daily life. However, the problem gets aggravated for them when their complaints do not get resolved and they do not get timely relief. This study focuses mainly on discovering the potential causes of delay in complaint resolution process in the PCP. This is done by using a modular approach deploying a natural processing language and Lean Six Sigma (LSS). The earlier part of the modular approach is used for introducing an element of priority whereas its later part is used to streamline the existing complaint resolution process in the PCP by removing waste in the form of non-value adding activities and variance. An algorithm has been developed for this purpose which detects the particular keywords related to price control and highlighting them for getting resolved on priority basis. It is noteworthy that this study focuses only on price control domain of the PCP. Moreover, this study also presents a comparative analysis of the existing process, the process after application of LSS only and the process after application of the modular approach of this study. It can be seen that the existing overall complaint resolution time is around 40 days. After the application of LSS, it was reduced to around 31.5 days. However, using the modular approach of this study, it was successfully reduced to around 21.5 days, thereby increasing the overall efficiency of the PCP by around 48 percent and hence serving the ultimate purpose of public satisfaction.

Index Terms- Lean Six Sigma, Pakistan Citizen Portal, Complaint Resolution System

I. INTRODUCTION

With the passage of time, life has evolved significantly. There have been major changes in how the mankind has been thriving on the planet earth. These changes have inspired increased desire in human beings for more and more amenities and ease in life. This ever-increasing desire coupled with the competitive challenges from the rivals in the industry, have compelled the industry to opt for different strategies to try to live up to the expectations of their customers. For instance, they have been seeking increased value in their products and or services. According to Antony, *et al*, 2018, this drive has spread beyond manufacturing industry into the service industry, whether through higher quality, faster delivery, cost efficiency, or a combination of the three [1]. To know about the requirements of the customers and to be able to think one step ahead of them, it is imperative that organizations and industries have a system of getting feedback from their potential customers. One such system is a complaint resolution system. A complaint resolution system is used by the customers to register their grievances regarding a particular product or service. This way, an organization or industry gets a good idea of what their target audience want, and how they need to steer their direction in the future. This study focuses on the Pakistan Citizen Portal (PCP) as a case study complaint resolution system. Like any other system, the PCP offers room for improvement in terms of efficiency. Therefore, to address the issue at hand, two process excellence (PE) approaches, Lean and Six Sigma, come to the fore as important tools for improving efficiency and effectiveness of the process (Anthony, *et al*, 2017) [2]. These PE strategies have a proven history of bringing improvements in quality of a product, service delivery, increasing profitability for a company, and other competitive advantages in the long run, thereby generating satisfaction on part of the customers. Lean focuses on removing waste or the unnecessary steps and complications from a process such as excessive waiting time, etc. On the other hand, Six Sigma mainly focuses on cost reductions or process variation (Montgomery and Woodall, 2008) [3]. As a result, both approaches have been combined to form a holistic PE tool namely Lean Six Sigma (LSS) for better results (George, 2002) [4]. However, this study will be using a more advanced form of the process improvement tool in the form of a modular approach deploying an integration of a natural processing language and LSS for bringing improvement in complaint resolution time (CRT) as well as introducing the element of priority regarding complaints related to price control to be resolved based on specific keywords.

The Pakistan Citizen Portal receives a large number of complaints regarding violation of official prices of essential commodities on a daily basis. A lion's share of these complaints are not resolved timely which leads to frustration and resentment on part of the public at large. The main reasons for this inefficiency lies within the PCP itself and how it is operated. Once a complainant lodges a complaint, it is firstly assigned to an officer at district level. Then, the same complaint is circulated among various officers, and by the time it reaches the officer concerned, a lot of time has already been wasted. The figure 1 shows that the PCP covers many domains of daily life. The focus of this study will be addressing the complaints regarding price control as it is a domain where the majority of the complaints are registered.

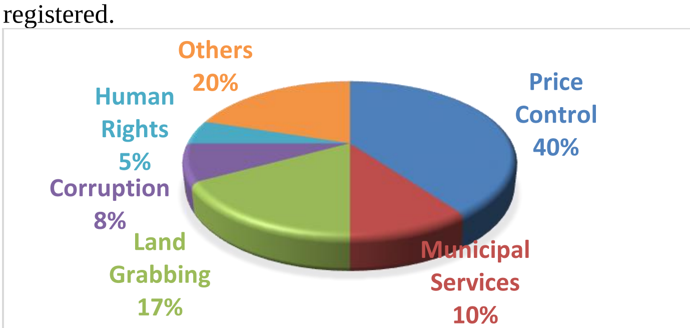

Figure 1: A Sample Size of 300 Complaints Received in PCP Dashboard for Sub-division Khwazakhela Swat

The main objectives of this study include investigating the potential causes of delay in the resolution of complaints regarding price control for essential commodities in the PCP. Also, to streamline the complaint registration process by reducing the non-value adding activities in the process and to increase the efficiency of the PCP by reducing the overall complaint resolution time and introducing an element of priority regarding price control domain.

II. LITERATURE REVIEW

To keep the customer pool intact, the industries and organizations are constantly looking for ways and methodologies to bring improvement in their products and or services. Among many such methodologies, the Lean Six Sigma is the widely acknowledged process excellence (PE) practice (Albliwi and Antony, 2015) [5]. While these two PE practices are meant for the same purpose, there is still room for improvement in each; therefore, an integrated version of the two is a more improved and better tool for bringing improvement in a system. According to Snee, 2010, Lean is a bottom-up strategy empowering front line staff to think and implement the improvements, whereas Six Sigma is more a top-down approach where management engages a few niche skilled-belts to introduce process transformations [6]. A lot of work has already been done in the application of LSS as a process excellence approach. Gomaa AH, 2024 conducted a study wherein the implementation of the LSS was done in a spare parts company based in Egypt. Based on the results of the study, different suggestions were made. Consequently, among other factors, the total effective equipment performance (TEEP) improved from around 58 percent to over 67 percent; overall equipment effectiveness (OEP) improved from around 64 percent to 75 percent [7]. Likewise, Faishal M *et al,* 2024 analyzed the problem of huge waste due to defective products amounting to 10.2 percent of the entire production. The defects compelled the company to face huge losses as well as compromise quality. The results of the study successfully disclosed the bottlenecks which is expected to reduce the disability in the process by around 50 percent [8]. In a related research study, Turna GB *et al,* 2023, applied the Lean Six Sigma approach in a stainless steel manufacturer in Türkiye for improving the production process. They were successful in identifying the root causes in tension unit, carpet cleaning, coating unit, film surface, etc. As a result of the counter measures came up in the LSS methodology, they were able to reduce the defect rate from 0.21% to 0.08% [9]. Similarly, Condé GCP *et al,* 2023, sought to reduce waste and improve product quality in a car parts manufacturing industry. As a result of implementation of the suggestions put forward by their study of LSS, they successfully reduced the defect incidence from a chronically high level to an acceptable one, thereby raising the sigma level from 3.4 s to 4 s and making the overall process sustainable [10]. Likewise, Ramadan MA *et al,* 2022, implemented the methodology of LSS as a process enhancement tool in hotel industry in the United Arab Emirates (UAE) to reduce the cycle time of a pantry workstation. As a result of the study, they were able to significantly reduce the average cycle time and standard deviation of the pantry process. Consequently, the improvement was reflected in the form a profit of over $50,000 per year [11]. In another study by Sisman G *et al*, 2023, the LSS approach was implemented with the objective to bring down the cost of logistic in a case study in Türkiye. After the implementation of solutions, the quality of product and internal communication of the company was ameliorated. This led to the reduction of the customer orders by road from 13 percent to 5 percent which ultimately reduced the percentage of cost by road, paid by the company, from 5 percent to 1 percent [12].

In the same manner, Vo Ngoc Mai Anh *et al,* 2023, used the DMAIC approach to reduce the defects from 31.2% to 4.5% and increase the productivity per hour per person from 15 units to 30 units in a mechanical product process industry [13]. A Sharma *et al,* 2021, used DMAIC along with other tools to reduce defect rates and increase capacity of production in automobile light manufacturing industry; the results of the study showed a 53 percent success [14]. Similarly, the Lean Six Sigma methodology was leveraged for reducing defects and rejections from 12% to 4% in a filter manufacturing industry (Guleria P *et al,* 2021) [15]. Likewise, Trakulsunti Y *et al,* 2021, illustrated that the use of LSS could reduce the number of dispensation errors from 6 to 2 per 20,000 inpatient days in a month, thus translating into a total of around 66 percent reduction [16]. According to Kenneth C. Hohmeier *et al,* 2022, the use of the DMAIC framework in selected locations of a US-based large pharmacy chain for improved recommendation techniques led to higher rates of pneumococcal vaccination in high risk adult population [17]. In another research study, an integrated approach of LSS and Internet of Things (IoT) has been used to in a contractor manufacturing industry and successfully reduced the rejection rate of contractors which saved a total cost amounting to over Rs. 5 million per year (Santosh B. Rane *et al*, 2023) [18].

In the same way, Minh Ly Duc and Que Nguyen Kieu Viet, 2022, conducted research to reduce waste in the process of assembling mechanical products by applying the DMAIC process which saw a reduction of around 60 percent annually [19]. In the same manner, a pharmaceutical manufacturing site faced backlogs in customer orders in the wake of increased demand of the brand. Among others, manufacturing packaging line downtime was identified one area causing the backlogs. The introduction of LSS framework reduced the downtime which led to savings of just under half a million dollars (Byrne B *et al*, 2021) [20]. In a study by Alfaro CR *et al*, 2020, the LSS methodology was employed in a Costa Rican forensic department to reduce the number of pending cases with a backlog of more than 3 months by 97 percent and the turnaround time from 4 months to 1 month [21]. Madhani PM, 2020 showed through his study that the deployment of LSS as a process excellence tool triggered the net income of a retailer to go up by around 15 percent [22]. Thakur V *et al*, 2023 applied LSS tool in a healthcare setting to improve quality that is concerned with patient satisfaction [23]. In a related study, the DMAIC framework of LSS was used with value stream mapping (VSM) for industry 4.0 to improve the picking workstation design with a human-centered approach. As a result, the yield rate was improved from 98 percent to 100 percent which translated into a direct savings amounting to Euro 3180 (Wang FK *et al*, 2022) [24]. In the wake of the COVID-19, the need for using the limited healthcare resources in a more efficient and effective way was highlighted. In this regard, around 20 % cardiac surgical cancellations in a university medical center in the Netherlands left negative impacts on these limited resources. Therefore, the LSS methodology was used to successfully to address the issue at hand (Schretlen *et al*, 2021) [25].

Furthermore, Wheeler-Web J *et al*, 2019, improved scheduling, invoicing, quoting and paying for campus office moves in a university; the results of the study noted an overall improvement of around 27 percent [26]. In the same fashion, the LSS was employed in a manufacturing company based in Brazil to improve productivity. The implementation of the framework introduced an enterprise-wide culture of project with huge benefits (da Silva IB *et al*, 2020) [27]. Nandakumar N *et al*, 2020, successfully implemented the process enhancement tool of LSS in a food processing industry with the aim to point out the stumbling blocks and make the production process better [28]. Conceição RS *et al*, 2019, followed the DMAIC structure for cost management orientation and increasing the capacity of the process in an agro-industrial cooperative department; the results noted were brilliant [29]. Alkunsol WH *et al*, 2019, investigated the effect of Lean Six Sigma elements on a pharmaceutical business based in Jordan. They were able to show that there existed a robust relationship between the LSS and the business performance [30].

Additionally, Antonio, H.H Pereira *et al*, 2019, applied the process improvement technique of LSS to enhance the mould industry by optimizing the internal process of production [31]. Minh Ly Duc and Minh Nguyen Thu, 2022, successfully made use of Lean Six Sigma to control fluctuations in the machining line improving the overall productivity of the line, thus making important contribution to raise the quality and competitiveness of the mechanical plant. To be specific, the outcome of the mechanical plant was raised from 115 products per 8 hours to 155 products in the same time slot. This led to the reduction of the handling time from 1.3 per day to 0.36 hours per day [32]. Rajeev Rathi, *et al*, 2022, implemented the concept of Green Lean Six Sigma (GLSS) to bring improvement in process and environmental parameters such as cycle time and lead time [33]. Rachel Brown, *et al*, 2019, applied LSS as process excellence tool to improve rates of day of surgery admission (DOSA) in a national thoracic surgery department. Over a period of 19 months, DOSA has seen an increase of over 70 percent. In addition, the duplication of tests before the surgery reduced to less than 2 percent from the existing 83 percent [34]. Milad Haerizadeh and Vijaya Sunder M, 2019, applied the DMAIC-based LSS to improve education system in a university in Iran. They were able to improve overall rating by 10 percent, reduce student advising wait time by 15 percent, and increase enrollment by 5 percent; consequently, improving the overall education system as desired [35]. LT James T. Flanary, *et al*, 2020, used LSS to improve access to care (ATC) in a surgical susceptibility clinic. They were successful in reducing the average days for a new consult to be seen by 7.2 days in pediatric urology clinic and 6.4 days in the adult urology clinic. ATC standard increased from a baseline of 69.2 percent to around 88 percent and 61.7 percent to around 84.4 percent [36]. In a study by Selim Ahmad, 2019, an integrated approach combining LSS and theory of constraints (TOC) medical errors, medical costs, administration errors and defects were minimized [37]. Islam Ibrahim *et al*, 2022, employed LSS to improve timelines of clinical laboratory test results in a university hospital in Egypt. Results after the improvement reflect that only 1% of inpatient routine CBCs were verified later than the desired target compared to 19% earlier [38]. Andrew W. Kam, *et al*, 2021, were able to reduce duration and variability of patient in-clinic time and increase service capacity in outpatient ophthalmology clinics by using Lean Six Sigma as process improvement methodology. Specifically, the number of patients seen per session was increased from 19.4 to 21.1, a decent improvement of around 9 percent [39]. Nicola Wolfe *et al*, 2021 significantly improved the quality and timely production of an operation note (ON) in a private hospital in Dublin, Ireland using LSS. Their work paved the way for the ON to be 100 percent digital which translated to a cost saving of 10,000 Euros in a year. The digital nature of the ON reduced its production time by 30 percent as well as making it perfectly legible [40]. D. Jinil Persis *et al*, 2022 realized the importance of LSS by employing it to remove bottlenecks and ameliorate key indicators such as patient turnaround time (TAT), workforce utilization and others. The post-implementation of the study situation led to a savings of over 40,000 USD per year [41]. Noronha *et al*, 2023, deployed the LSS strategy and assisted the Endodontics department in healthcare setting to reduce the processing time from 116 mins to 84 mins [42]. Manjeet *et al*, 2022, used LSS as process improvement methodology in case of a juice manufacturing company that had been suffering from huge wastage problem. The company was able to reduce its wastage issue by 50 percent and as well as increase its profit by 7 percent [43]. The post implementation scenario of LSS as process enhancement tool in a private hospital day care unit reflected a reduction in patient turnaround time, increase in nursing care time, and amelioration in the nurse-patient ratio (Davies C *et al*, 2019) [44]. Huay Ling Tay and Hui Sen Aw, 2021 successfully identified the root causes to improve the supplier selection process of a large health company [45]. Ilesanmi Daniyan *et al*, 2022 brought healthy improvement in the assembly process of bogie in the railcar industry. They were able to improve the process cycle efficiency by 46.8 percent, reduce lead time by 27.9 percent, increase the value-added time by 59.3 percent, and reduce the non-value-added time by 71.9 percent [46].

In addition, the LSS has been widely adopted as a business strategy and technique in a variety of industries, including healthcare, higher education, and small and medium-sized firms, etc. It is a driving force for continuous improvement, allowing firms to eliminate inefficiencies and increase customer satisfaction (Bendell, 2006; Antony et al., 2016) [47][48]. Dagne TB *et al*, 2023 applied a customized form of DMAIC framework for the improvement of garment manufacturing process in industry in Ethiopia. The implementation of the research study was able to introduce improvement by lowering lead time by around 36 percent and increasing labour productivity by over 25 percent [49]. Vazquez-Hernandez J *et al*, 2023 used Lean Six Sigma with the concept of industry 4.0 and digital transformation to detect cold weld defects in a steel pipe manufacturing company. The study was able to detect 87 percent of the cold weld defects as well as reduce employee inspection errors [50].

The above discussion has been tabulated in the form of Table 1 that is attached at the end as Appendix 1. From Appendix 1, it becomes evident that use of Lean Six Sigma (LSS) for improving processes in different industries has been common. However, its use in service sector in general and in complaint resolution systems in particular has been scarce. Moreover, it also becomes clear that two important aspects in a complaint resolution process including priority of complaints and resolution time of complaints have not been worked on overwhelmingly. Therefore, this study will focus on fulfilling this gap by considering the case study of Pakistan Citizen Portal.

III. METHODOLOGY

The methodology adopted for this study comprises mainly of the DMAIC approach of Lean Six Sigma. The DMAIC stands for Define, Measure, Analyze, Improve and Control. At first, the key performance indicators of complaint resolution time (CRT) and priority of complaints are defined and a target for their improvement is set in the define phase. Second, the existing complaint resolution process in the PCP is evaluated in the measure phase. Third, in the analysis phase, the important and non-important activities in the existing process of complaint resolution is discussed. Fourth, the improve phase discusses how the non-value adding activities are replaced with the introduction of a natural processing language. Finally, the control phase discusses ways to sustain the improvement. Figure 2 illustrates the overall methodology.

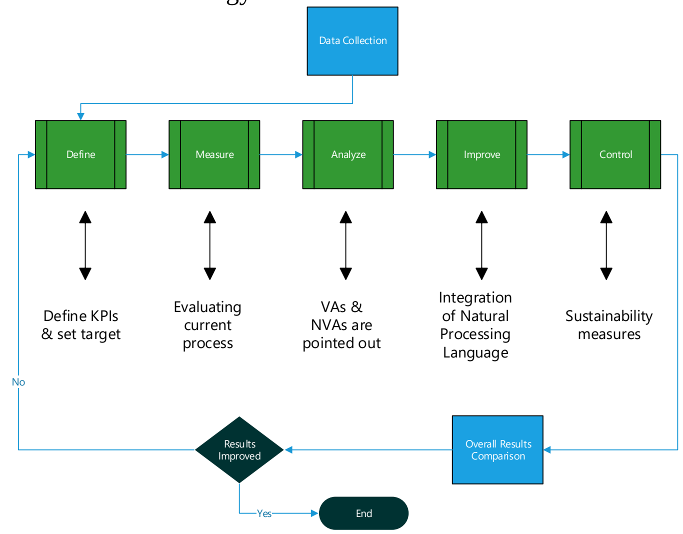

Figure 2: Flow Chart of the Proposed Research Methodology

○ The Define Phase
In this phase, the problem is clearly defined. The Key Performance Indicators (KPIs) that are critical to PCP and need improvement are pointed out. In this case, those KPIs are complaint resolution time (CRT) and priority of the complaints. The CRT means the time taken from the registration of a complaint by a user till the complaint is officially closed by the concerned department. Similarly, the priority of a complaint implies that complaints with particular keywords be resolved on priority basis. For this study, the potential keywords include: overpricing, overcharging, no price list, etc. This study will put to effect a modular approach, an integration of the LSS and a natural processing language, to bring down CRT near 20 days as compared to the current duration of 40 days as well as introduce an element of priority for particular complaints to be resolved based on specified keywords. Those keywords will be mainly related to the domain of price control which is the underlying focus of this study.

○ The Measure Phase
During this phase, the goal is to collect data, study the current process, and assess its initial performance. For instance, the data of complaints registered in a span of time in the past, the time it took for resolution, etc. The data collected from the PCP for the past four months (around 300 complaints) for subdivision Khwazakhela district Swat indicate that the existing average CRT is around 40 days as depicted in figure 3. After 40 days, if not resolved and closed, the complaint gets escalated. If it lasts beyond 60 days, the complaint gets super escalated.

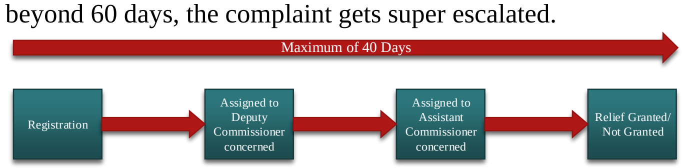

Figure 3: The Existing Complaint Resolution Process

The Figure 4 below is a screenshot from the official app of the PCP, confirming the time duration mentioned in the above figure 3.

Figure 4: The Time Duration Currently taken for Resolution of a Complaint in PCP

○ The Analyze Phase

In this phase, the potential causes for delay in the resolution of complaints are analyzed. In other words, the objective is to find out the bottlenecks that create the variation in the process. For this purpose, the existing process of complaint resolution in PCP is broken down into value added (VA) and non-value added (NVA) activities. For this purpose, let's dive deep into the existing complaint resolution process. The figure 5 below depicts with the help of clearly outlined steps how a complaint is currently registered by a complainant, and then how it is processed by the PCP.

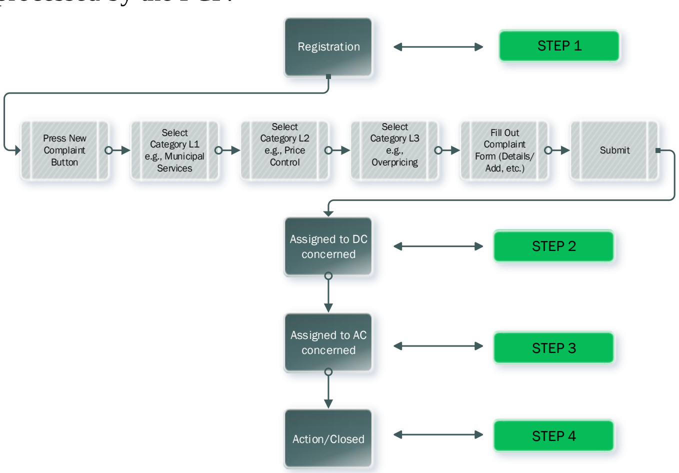

Figure 5: Step-wise break down of a complaint resolution process in the PCP

Now, based on the existing operation of the PCP, the time taken (in days) by each step in Figure 5 is further elaborated by Figure 6 below.

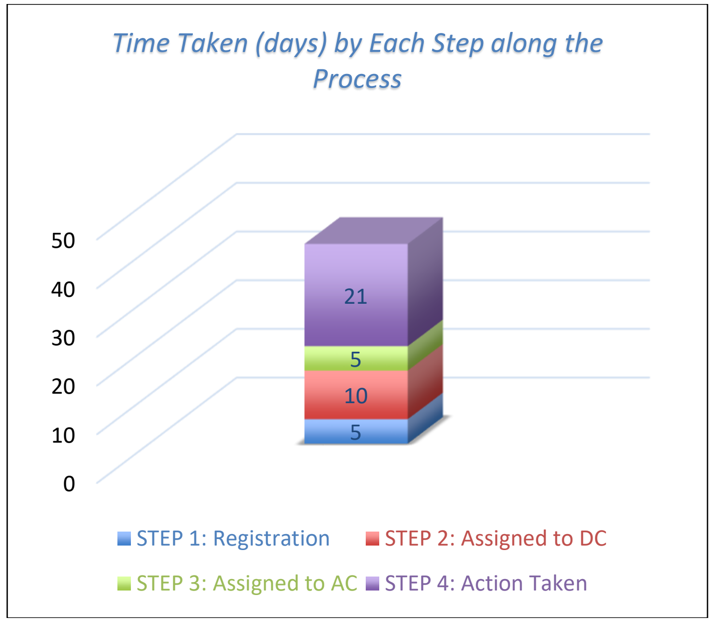

Figure 6: Breakdown of Step-Wise Time Taken

Moreover, after deliberation upon figure 5 and figure 6, some non-value adding activities (NVAs) were pointed out. Additionally, some brainstorming sessions were held wherein other factors responsible for delay in complaint resolution were also noted down. The Fishbone Cause & Effect diagram in the form of figure 7 summarizes those NVAs.

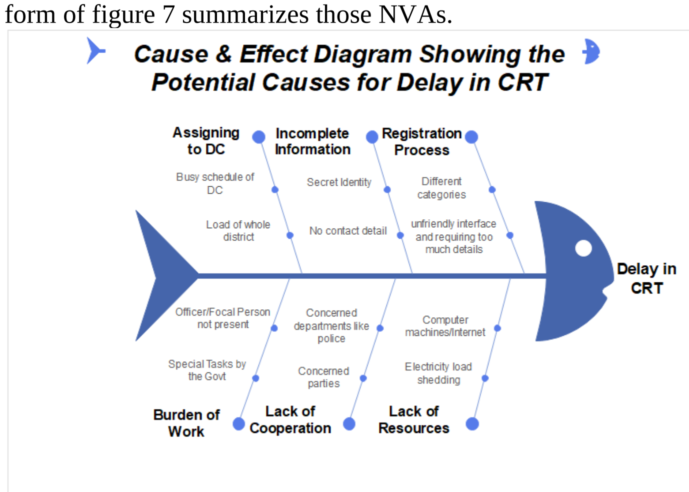

Figure 7: Fishbone diagram showing potential NVAs in existing CRT

○ The Improve Phase

The purpose of this phase is to find out solutions to the selected causes of delay that are identified in the Analyze phase, implement those solutions, and finally observe the outcome so that the process can be improved (Gijo *et al.*, 2018) [51]. Now, the NVAs pointed out in the previous phase were removed from the existing complaint resolution process and the results were compared with the current outcome. By employing this approach, the average CRT was successfully reduced to under 31.5 days compared to the current 41.5 days. The average CRT in both cases was found using the Minitab statistical software. Secondly, a modular approach deploying the LSS and a Natural Processing

Language was used. In this approach, a keyword detection algorithm was developed for taking the text of a complaint as input. The algorithm would process the text of the complaint and compared it with its own list of pre-specified keywords in accordance with the particular domain selected for this study. Based on that, it assigned priority to a complaint containing only the important keywords in its text and printed them in output as highlighted in Figure 8. By using the modular approach, the process of complaint resolution was streamlined by reducing the waste in the form of NVAs. Consequently, the average CRT was minimized to 21.5 days. The outcome was achieved using the Minitab statistical software. Thus, the introduction of our own algorithm brought an element of priority for complaints regarding price control whereas the application of LSS reduced variance and waste from the CRT, making it more time-efficient.

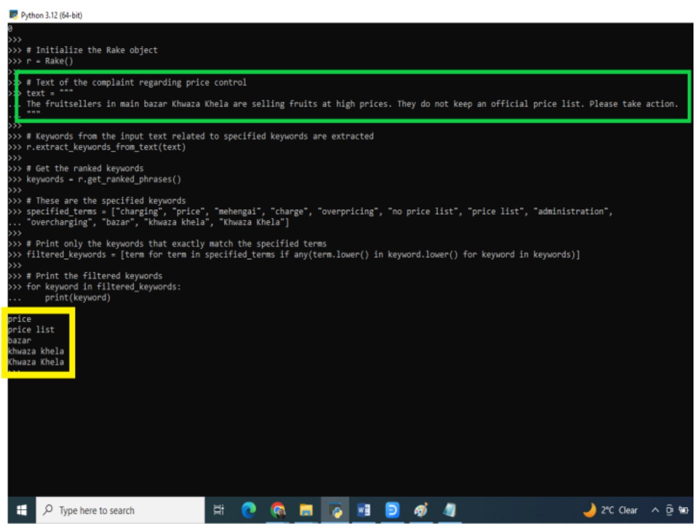

Figure 8: The Natural Processing Language Detecting Specific Keywords

○ The Control Phase

In this phase, ways were defined for sustaining the achieved improvement. First, it was considered that concerned employees operating the PCP would be trained periodically so that proper response to the complaints would be ensured. Secondly, it was considered that a monthly review of the performance would be planned so that the progress of the system might be analyzed. Thirdly, the feedback report from the complainants would be regularly generated and further improvements be brought in light of that feedback.

IV. RESULTS

This section provides a detailed overview of the outcomes of the study. The Minitab software was mainly used for analysis and comparison of data. First and foremost, a random sample of 100 complaints from the PCP was tested to find out its normality and the existing average CRT. Figure 9 below depicts that existing average CRT was 41.5 days.

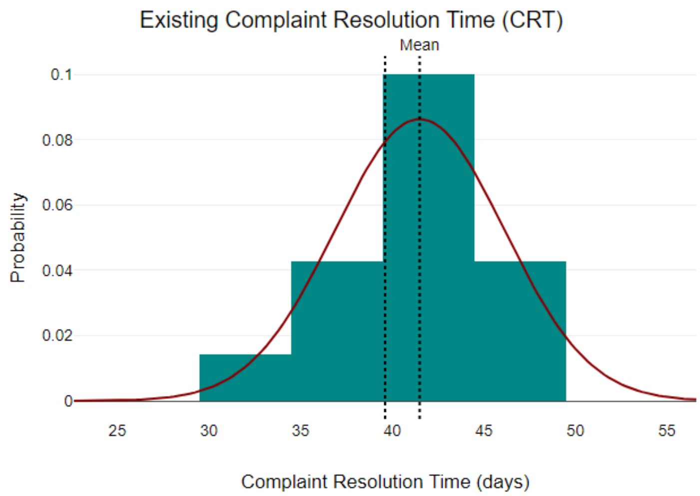

Figure 9: Normality Test of Existing CRT

Now, the methodology of Lean Six Sigma (LSS) was taken into account for improving the average CRT. As discussed above in Improve phase, the complaint resolution process was streamlined by identifying and removing some NVAs in line with the LSS. Consequently, the average CRT was reduced to 31.5 days. This led to a significant decrease of 10 days in the existing CRT. Figure 10 below clearly depicts the new average CRT after LSS.

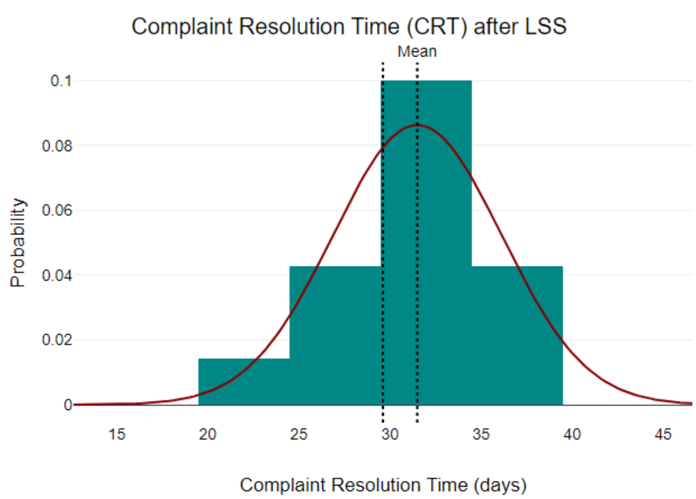

Figure 10: Normality Test of CRT after LSS

After the application of LSS, the modular approach was employed to bring further refinement in the complaint resolution process. As anticipated, the average CRT after the application of the modular approach was improved by another 10 days and reduced to only around 21.5 days. Figure 11 below verifies the aforesaid statement.

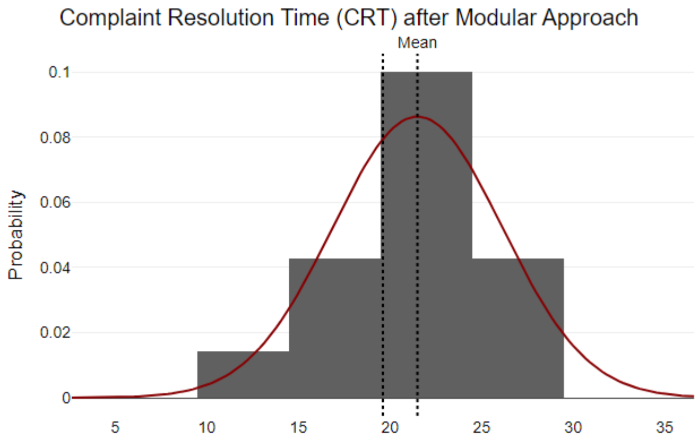

Figure 11: Normality Test of CRT after Modular Approach

Lastly, a comparative analysis was done using bar chart in Microsoft Excel. As shown by figure 12 below, a comparison was drawn between the existing average CRT, average CRT after LSS, and the average CRT after the Modular Approach. It was found that employing the LSS methodology led to an improved average CRT by decreasing it by around 24 percent. However, upon employing the Modular Approach of this study, it was revealed that the existing average CRT could be improved by around 48 percent. This translated a reduction of minimum 20 days in the existing complaint resolution process, which is a significant improvement.

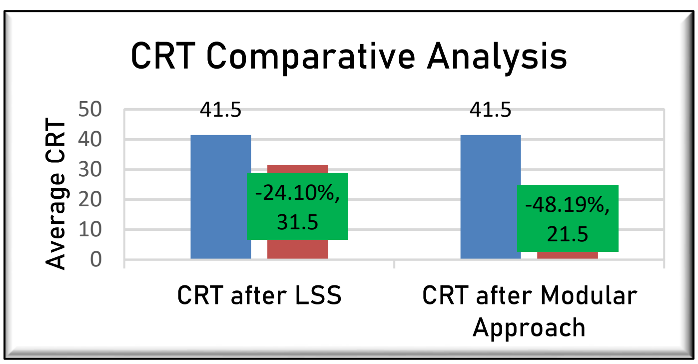

Figure 12: Comparative Analysis of Average CRT

V. CONCLUSION

The outcome of the study testifies that significant improvement has been brought in the complaint resolution process of Pakistan Citizen Portal by mainly reducing the complaint resolution time. This was chiefly achieved by the application of LSS and the subsequent Modular Approach of this study. In the beginning, the analysis of the existing process revealed the CRT to be 41.5 days. The application of the LSS approach led to an improvement of 10 days making the CRT to be 31.5 days. However, the introduction of the Modular approach further fine-tuned the process and led to an additional enhancement of it by 10 days, thereby making the overall CRT to be standing at 21.5 days which marked an astonishing reduction of 20 days in the overall CRT compared to the initial analysis. In terms of percentage points, the LSS methodology caused 24 percent improvement whereas the Modular approach of this study brought about 48 percent enhancement in the process of complaint resolution that shows its high level of effectiveness.

This study covers only one major domain of price control within the Pakistan Citizen Portal, so the future work might be done in this direction to include other domains of the PCP such as encroachment, human rights, civil suits, and corruption, etc. In addition, it presents a foundation for organizations to achieve significant efficiency in their complaint resolution systems by making use of Modular approaches similar to the one used in this study. For instance, integration of emerging technologies with the fundamental process streamlining methodology of Lean Six Sigma could bear extremely good results in the future.

APPENDIX 1

S.No.	Authors	Year	Contribution	Components/Architecture	Limitations
1.	Goma AH [7]	2024	Performance Improvement like TEEP & OEP	Spare Parts Industry	Limited industry generalizability, single case study
2.	Faishal M *et al* [8]	2024	Waste reduction	Biomass production industry	Focus on short-term defect reduction, limited application in industry
3.	Turna *et al* [9]	2023	Reduction of defect rate from 0.21% to 0.08% in production process	Stainless steel industry	Limited generalization, company specific
4.	Condé GCP *et al* [10]	2023	Reduce waste and improve quality	Car parts manufacturing industry	Case study specific, limited generalization to other industries
5.	Ramadan MA *et al* [11]	2022	Reducing average cycle time/profit of over $50,000 per year	Hotel Industry	Limited industry applicability, focus on short term impact assessment
6.	Sisman G *et al* [12]	2023	Reduced the percentage of cost of orders by road from 5% to 1%	Logistics Industry	Industry & country specific, lacks generalization and focuses on single domain of logistic costs
7.	Vo Ngoc Mai Anh *et al* [13]	2023	Reduced defects rate from 31.2% to 4.5% and increasing productivity per hour per person from 15 units to 30 units	Mechanical product process industry	Industry specific, lacks generalization and focuses on single domain of reduced labour
8.	A Sharma *et al* [14]	2021	53 percent success in reducing defect rate and increasing productivity	Automobile light manufacturing industry	Industry specific, lacks generalization and focuses on single domain of defect reduction
9.	Guleria P *et al* [15]	2021	Reduced defects & rejections from 12% to 4%	Filter manufacturing industry	lacks generalization and focuses on single domain of rejection rate reduction
10.	Trakulsunti Y *et al* [16]	2021	Reducing dispensation errors from 6 to 2 per 20,000 inpatient days in a month	Health care industry	Research findings cannot be applied beyond the specific pharmacy setting
11.	Kenneth C. Hohmeier *et al* [17]	2022	Improved rate of vaccination	US-based pharmacy chain	Specific purpose (increasing a vaccination rate), limited generalizability,
12.	Santosh B. Rane *et al* [18]	2023	Reduced rejection rate of contractors	Manufacturing industry	Focus only on reducing rejection rate
13.	Minh Ly Duc and Que Nguyen Kieu Viet [19]	2022	Reduced 60% waste in the manufacturing process	Assembling mechanical products industry	Findings cannot be applied to other industries, focuses only on waste reduction
14.	Byrne B *et al* [20]	2021	Identifying backlogs and reducing downtime of orders, saving around half a million USD	Pharmaceutical industry	Industry specific, short term assessment

15.	Alfaro CR *et al* [21]	2020	Reduced the number of pending cases by 97% and turnaround time form 4 months to 1 month	Forensic department in Costa Rica	Lacks generalization, forensic specific
16.	Madhani PM [22]	2020	Increased the net income by 15 percent	Retail Industry	Focus on retail, short term impact assessment
17.	Thakur V *et al* [23]	2023	Improved patient satisfaction	Healthcare industry	Challenges in implementation, specific healthcare setting
18.	Wang FK *et al* [24]	2022	Improved yield rate form 98% to 100%	Industry 4.0	Manufacturing-centric, lacks generalization
19.	Schretlen *et al* [25]	2021	Improved cardiac surgical cancellation	Healthcare industry	Specific healthcare setting, focus on surgical cancellations only
20.	Wheeler-Web J *et al* [26]	2019	Overall improvement of 27% in execution of certain works	University office setup	External applicability is limited, focused on specific university setting
21.	da Silva IB *et al* [27]	2020	Improved productivity	Manufacturing company	External applicability is limited, focused on manufacturing aspect only
22.	Nandakumar N *et al* [28]	2020	Identified and reduced stumbling blocks in production process	Food processing industry	Industry specific emphasis on food processing, short term impact evaluation
23.	Conceição RS *et al* [29]	2019	Cost management and increasing process capacity	Agro-industrial department	Potential bias, industry specific focus
24.	Alkunsol WH *et al* [30]	2019	Improving performance	Pharmaceutical industry	Industry and country specific, generalization of results may be questionable
25.	Antonio, H.H Pereira *et al* [31]	2019	Optimized internal process of production	Mould industry	Insufficient industry specificity, limited contextual analysis
26.	Minh Ly Duc and Minh Nguyen Thu [32]	2022	Controlled fluctuations in machine lining process, improving productivity	Manufacturing industry	Heavy reliance on advanced technologies
27.	Rajeev Rathi, *et al* [33]	2022	Improved process and cycle time	Manufacturing industry	Complexity of life cycle assessment, dependence on modern technology
28.	Rachel Brown, *et al* [34]	2019	Increase of over 70% in rate of day of surgical admissions	National thoracic surgery department	Focus on specific center & country, require extensive resources, results may not stand different contexts

29.	Milad Haerizadeh and Vijaya Sunder M [35]	2019	Improved overall rating by 10%, increased enrollment by 5%, etc.	`University education system in Iran	Implementation of LSS in higher education is relatively a new topic
30.	Flanary, *et al* [36]	2020	Improved access to care (ATC)	Surgical susceptibility unit	Utilization of specific simulation software may pose challenges for replication in settings where different tools are available
31.	Selim Ahmad [37]	2019	Reduced medical error, cost errors, etc.	Health care industry	Limited practical evidence and applicability
32.	Islam Ibrahim, *et al* [38]	2022	Improved timeline of clinical laboratory test	University hospital in Egypt	Single-setting analysis
33.	Andrew W. Kam, *et al* [39]	2021	Increased the number of patients seen per session by 9 percent	Healthcare industry	Single clinic setting, short term analysis
34.	Nicola Wolfe *et al* [40]	2021	Improved quality and timely production of operation note	Private hospital in Dublin, Ireland	Lacking potential upfront implementation cost, short term impact assessment
35.	D. Jinil Persis *et al* [41]	2022	Removed bottlenecks and improved key indicators led to a savings of over $40,000 per year	Health care industry	Novel method for data analysis need more explanation for future work
36.	Noronha *et al* [42]	2023	Reduced the processing time from 116 mins to 84 mins	Endodontics department in health care setting	Specific setting of a dental college
37.	Manjeet *et al* [43]	2022	Reduced wastage by 50% and increase overall profit by 7%	Juice manufacturing company	Study is for a particular juice manufacturing industry only
38.	Davies C *et al* [44]	2019	Reduced patient turnaround time, increase nursing care time and nurse-patient ration	Private hospital day care unit	Interventions are not elaborated which makes it hard to be implemented in other similar settings
39.	Huay Ling Tay and Hui Sen Aw [45]	2021	Improved supplier selection process	Health care company	Limited scope and limited application
40.	Ilesanmi Daniyan *et al* [46]	2022	Improved assembly process of bogie	Railcar industry	Scope and external application limitation
41.	Dagne TB *et al* [49]	2023	Lowered lead time by 36% and increased labour productivity by 25%	Garment manufacturing industry	Technology dependence, resource constraints, context specificity
42.	Vazquez-Hernandez J *et al* [50]	2023	Detect 87% of the cold weld defects and reduced employee inspection errors	Steel pipe manufacturing industry	Limited scope of integration, specific case study

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