Yugoslav Journal of Operations Research
26 (2016), Number 4, 395-422
DOI: 10.2298/YJOR150815006R

A REVIEW PAPER ON OFFLINE INSPECTION OF FINISHED AND SEMI-FINISHED PRODUCTS AND EMERGING RESEARCH DIRECTIONS

Muhammad BABAR RAMZAN
Department of Industrial and Management Engineering, Hanyang University, Republic of Korea
babar_ramzan@yahoo.com
Chang WOOK KANG
Department of Industrial and Management Engineering, Hanyang University, Republic of Korea
Cwkang57@hanyang.ac.kr
Biswajit SARKAR[*]
Department of Industrial and Management Engineering, Hanyang University, Republic of Korea
bsbiswajitsarkar@gmail.com

Received: August 2015 / Accepted: December 2015

Abstract: Organizations want to focus on product quality along with productivity to get their competitive advantage in global market. In order to achieve this aim, quality management system and its different aspects are becoming more valuable than before. This study has considered quality control and its activities with specific focus on offline inspection, by providing a literature review that identifies different models and methodologies, developed for offline inspection under different manufacturing and inspection conditions. This review is based on research work accepted by international journals and published in the years from 2000 to 2016.These studies are classified into six groups on the basis of their research objectives, developed model, adopted methodologies, and research outcomes. This review paper also gives a brief look at the offline inspection to propose future research opportunities and emerging trends. The proposed research directions can be helpful in developing new models or modifying the existing models to improve the performance of offline inspection.

Keywords*:* Quality control, Inspection policy, Continuous sampling, Multi-stage manufacturing system, Process target values.

MSC: 00A71, 00B10, 90B25, 03C50, 93A30, 81T80.

1. INTRODUCTION

In the present era, Quality management system (QMS) is more valuable than before because experts believe that last century worked more on productivity while present century is focusing on quality [1]. Recent studies also rank quality as an important criterion for performance evaluation of a product along with innovation, efficiency etc. [2]. After the evolution of QMS, the challenge of market globalization was responded positively by manufacturing and service industries. The guidelines developed for ISO 9000 are the minimum requirement for the implementation of QMS. With the passage of time, concept of ISO 9000 was adopted and its guidelines were considered valuable for the improvement of product and process quality[3]. QMS has been divided into different parts on the basis of its tools and techniques that includes: quality planning (QP), quality assurance (QA), quality control (QC), and quality improvement (QI) [4]. The purpose of QP is to identify which quality standards are relevant to customer's need and to prepare action plans to bring about the desired results. QA uses procedures and systems to assure that all activities are being performed according to the defined standards to meet the required quality level. On the other hand, QC consists of monitoring activities that are being performed at different stages of manufacturing to decide the conformance and non-conformance of the product. It also took necessary action to mitigate the root causes of non-conform products. Lastly, the objective of QI is to focus on customers need, proactive works to improve quality, cost reduction, time delivery, and ethical values[4].

The present study has focused on QC that uses different control points and checking methods to ensure outgoing quality. Studies are conducted to aggregate different aspects of quality control that may have multiple benefits [5]. However individual activities of QC still have their significance in manufacturing industry. Inspection is considered as an important part of QC activities, even though it is not adding any value to a product. Instead, it is seen as a screening or decision making process to decide the conformance or non-conformance of a product manufactured [6]. Two most important types of inspection are online inspection and offline inspection [7]. Online inspection is performed to monitor quality level during the manufacturing process [8, 9]. However, sometimes it is not feasible due to operation type and time. In this situation, offline line is a suitable alternative that is performed after the completion of manufacturing process [7]. Process of offline inspection can be performed at the end of assembly line when the product is finished, or at different stages of manufacturing when the product is semi-finished. Offline inspection has been studied comprehensively by many researchers of QC during the last decade for different manufacturing industries. This study has evaluated the previous literature to present a review paper on offline inspection.

It is well-accepted that literature reviews can make effective contributions to relevant field by highlighting its short comings [10]. There is a lack of such studies on offline inspection except those conducted by Shetwan *et al.* [11], and Mandroli *et al.* [12]. However, both of review papers were very specific and worked only on the allocation of quality control stations in multi-stage manufacturing system. The objective of the present work is to evaluate the existing literature on offline inspection with respect to their study objectives, presented models, selected parameters, assumptions, and adopted methodology. For this purpose, a literature review is conducted of all research papers published from 2000th to 2016th. Finally, it has also highlighted the gap in the under study field to identify the future research directions and emerging trends.

2. METHODOLOGY

This literature review was conducted according to the steps of systematic literature review (SLR) studied by Colicchia and Strozzi [13]. Process flow of *SLR* is shown in Figure 1. The complete methodology of this study follows three steps that include: criteria for selection of studies, defining database to select studies and data analysis.

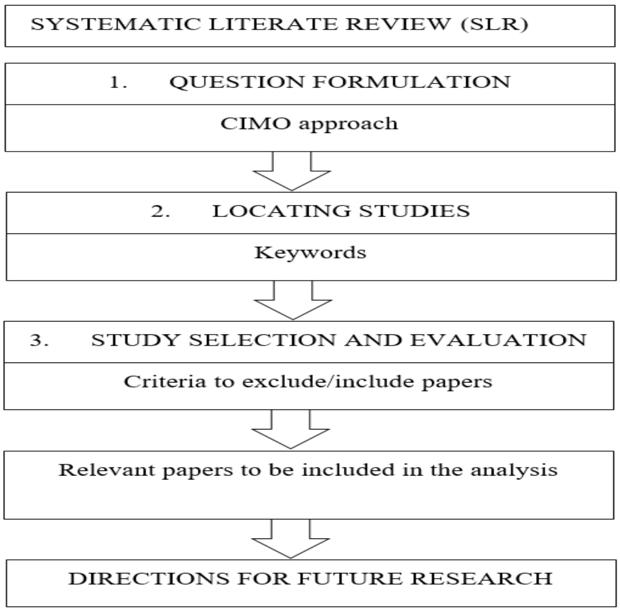

Figure 1: Process flow of systematic literature review[13].

The criterion for selecting the studies (only research papers on offline inspection are selected) was that papers were published in international journals, whereas theses, dissertations, books and reports related to offline inspection are not included. For fairly recent perspective of offline inspection, published papers are selected from the year 2000 to year 2016. After defining the criterion of selecting the studies, different databases were defined to search for the required published papers. Some of these databases are Tayler and Francis, INFORMS, Elsevier, Research academy of social sciences (RASS), etc. However, research papers which do not belong to these databases but are highly relevant to the under study field, are also included. Finally, the literature review was collected according to the defined criteria and information were collected. These information includes citation of paper, research strategy, research objective, methodology, assumptions, and main results. The research objectives and results were considered as a main source to divide all the selected studies into six major groups as shown in Figure 2. These groups include optimal inspection policy, inspection disposition policy, continuous sampling plan, optimization of process target values, multi-stage manufacturing system, and K stage inspection rework system. Literature survey relevant to each group was then extensively evaluated to describe research model, inspection strategy, and research outcome. On the basis of gap in research or deficiency in presented model, emerging trends and future directions are also highlighted.

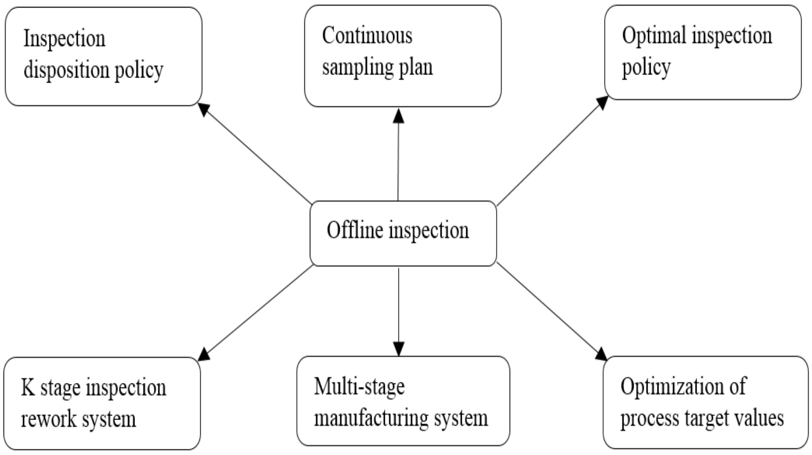

Figure 2: Classification of studies on offline inspection.

3. RESULT AND DISCUSSION

By using different keywords related to offline inspection, published papers were searched from the defined databases. After applying the inclusion and exclusion criteria, relevant documents from the year 2000 to 2016 were selected. Figure 3 indicates the number of papers published per year that are selected for this study. These selected publications belong to different data bases that includes Taylor and Francis, Elsevier, INFORMS, RASS, etc. This study is based on 54 papers published in international journals. In Appendix I, we have shown how the papers were selected from each database, and in Appendix II, we give the summary of the mentioned papers. Finally, all the selected papers were evaluated and divided into six groups on the basis of study objectives and research outcome. Figure 4 shows the summary of six groups and contribution of each group with respect to total number of studies offline inspection in the last sixteen years. Each group of publications was separately evaluated regarding research problem, study purpose, research methodology, assumptions, and research outcome.

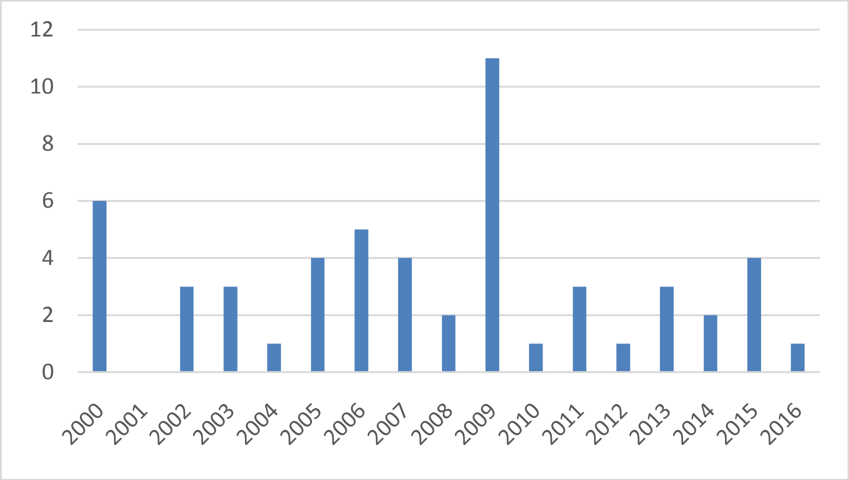

Figure 3: Number of papers published per year on offline inspection from 2000 to 2016.

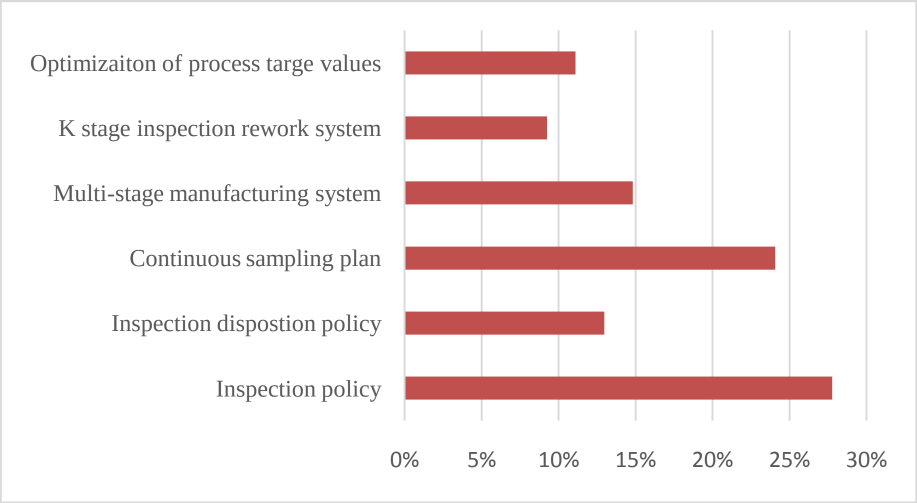

Figure 4: Contributions of all six groups in the research of offline inspections.

3.1. Optimal inspection policy

For the inspection of finished or semi-finished products, it is very important to decide on how to inspect and how many units should be inspected. This process of inspection has different names like inspection strategy, inspection plan, and inspection policy. Much work has been done to determine the optimal inspection policy for offline inspection. These inspection policies were helpful in minimizing the cost which is not only related to inspection but also setup, maintenance, production and shortage cost. Herer and Raz [14] worked on optimal parallel inspection for finding the first nonconforming unit (FNU) in a batch. Their optimal inspection policy provided a model that determines, at the same time, which unit should be inspected and how many units should be inspected. This solution reduced the uncertainty to locate FNU and minimized the total cost for a given batch size, process failure, and cost structure. Similarly, a generalized inspection policy was developed to calculate the optimal lot size and the expected number of inspections [15]. Numerical results indicated that inspection cost will not be affected by lot size if the yield is binomial. However, optimal lot size decreases the inspection cost for discrete yield. It was concluded that lot size depends on the inspection cost in a multiple production run. Sheu *et al.* [16] also developed an inspection policy for finite batch production process with inspection errors. The effect of inspection error on optimal solution of the presented model was studied. It is determined which unit should be inspected and how many inspections should be conducted to keep inspection cost low. Finally, comparison of total cost was done with three policies that include cost minimizing, perfect information, and zero defects.

In another study, the optimal lot size and the offline inspection policy were determined by Anily and Grosfeld-Nir [1] for batch production process. They formulated their research problem as partially observable Markov decision process (POMDP). The study included two main objectives: production policy and inspection policy. Production policy determines the optimal lot size, while inspection policy determines the optimal rule when to stop inspection. The ultimate target of both objectives is the assurance of zero defect delivery at a minimum expected total cost that includes production cost, inspection cost, and shortage cost. Similarly to Anily and Grosfeld-Nir [1], POMDP with two time parameters including the remaining demand and the number of non-inspected units [17], was further investigated. However, their problem can be separated into the production problem and the inspection problem. Production problem will find out the optimal lot size that should be produced, and inspection problem will give the quality level of previously inspected units. Anily and Grosfeld-Nir [1] worked on single production run with shortage cost, while Grosfeld-Nir *et al.* [17] considered multiple production runs with rigid demands. Their objective was to provide optimal inspection policy that can guide manufacturer to inspect the next unit of producing a new log.

Wang and Meng [18] also worked on offline inspection and developed a joint optimization model for lot size and inspection policy to determine the total cost function that included setup, maintenance, and quality related cost. Their inspection model was compared with three different inspection policies like no inspection, full inspection, and disregard the first*s* (DTF- *s*) items policy by numerical example. Theoretical aspect of offline inspection was extended with considering the inspection error to develop an optimal offline inspection policy [7]. It was assumed that when offline inspection is performed after the completion of batch, inspection is subject to error. Their presented inspection policy determined the optimal number of units to be inspected and the expected number of inspections. The objective was to determine the transition unit with a certain confident level while the offline inspection may have inspection error. Optimal inspection policy was developed by dynamic programming (DP) and compared with four heuristics policies, as well. All four heuristics have two basic steps, described in Figure 5.

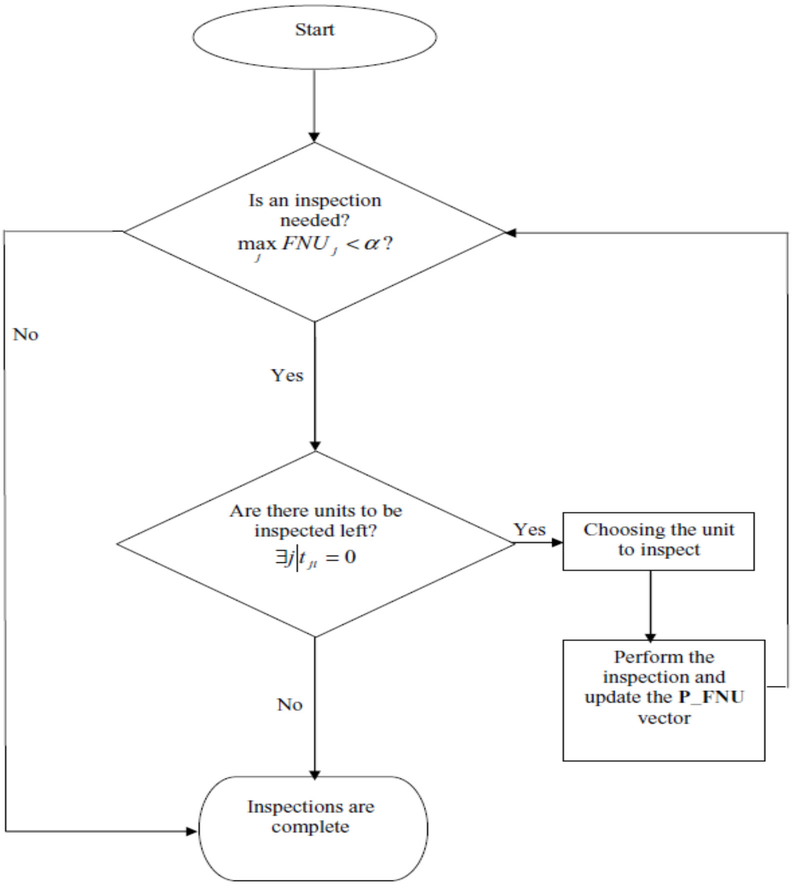

Figure 5: Flow chart indicating two basic steps of each heuristics.

Production process can either be stable or unstable while producing the batch of products. Under such process, estimating the desired level of quality of the batch can only be done by inspecting a sample of products. This type of production process was studied by Avinadav and Perlman [19] to minimize the total cost of batch that includes the cost of inspection, false rejection, and false acceptance. An economic inspection plan was presented to determine the optimal inspection interval that minimizes the total cost of a batch. A short communication was written by Aust *et al.*[20] on quality investment and inspection policy in supplier-manufacturer supply chain. They worked on one supplier and one manufacturer and considered inspection cost and inspection error.

Modified algorithm was provided to get optimal solutions that lead to high profit. Balamurali *et al.* [21] worked on mixed sampling plan that combines attribute sampling plan and variable sample plan. A methodology was designed and optimized solutions were presented to determine the plan parameters of proposed policy. The characteristic function of the proposed plan is derived, and Comparison was done with attribute sampling plan. It is concluded that the proposed plan is efficient in terms of higher probability of lot acceptance.

Most recently, a production inspection policy is developed by Sarkar and Saren [22] for an imperfect manufacturing system that has inspection error and warranty cost. Their objective was to reduce the inspection cost of a process that randomly shifts to out of control state from in control state. Table 1 shows the summary of research works that developed inspection policy for offline inspection. It indicates the contribution of different authors with respect to inspection plan, methodology, and study objective.

Table 1: Contribution of the previous research in developing optimal inspection policy.

Authors	Inspection			Penalty cost	Methodology	Study objective
	Plan	Error	Cost			
Herer and Raz [14]	Sampling		✓		DP	Optimal inspection policy
Grosfeld-Nir *et al.* [15]	Sampling		✓			Optimal lot size
Sheu *et al.* [16]	Sampling	✓	✓		DP	Effect of inspection error on optimal solution
Anily and Grosfeld-Nir [1]	100% and sampling		✓		POMDP	Optimal inspection policy
Grosfeld-Nir *et al.* [17]	sampling		✓		POMDP	Optimal policy to select between inspect produce
Wang and Meng [18]	100% and sampling		✓			Optimal policies for product inspection and lot size
Tzimerman and Herer [7]	Sampling	✓	✓	✓	DP	Optimal inspection policy
Avinadav and Perlman [19]	Sampling	✓	✓	✓	Solution algorithm	Economic inspection plan
Aust *et al.* [20]	Sampling	✓	✓	✓	Solution algorithm	Inspection policy in two level supply chain
Balamurali *et al.* [21]	Sampling		✓		Optimized solutions	Mixed sampling inspection policy based on EWMA
Sarkar and Saren [22]	Sampling	✓	✓	✓		Product inspection policy

3.1.1. Repeat inspection plan

Another type of inspection plan, known as general repeat inspection plan was developed for systems that deal with multi characteristics critical components like air craft, gas ignition system or space shuttle, etc. [23-26]. One of the pioneer work on multi characteristic critical components was done by Duffuaa and Khan [23]. They worked on optimal repeat inspection plan with several classifications of a product by quality inspector and came out with a generalized new model.They proposed a categorization of non-defective product as rework or scrap, with respect to a certain characteristic. Their objective was to minimize the total expected cost that includes inspection cost and misclassification cost. Figure 6 shows the flow process of repeat inspection plan adopted by Duffuaa and Khan [23].

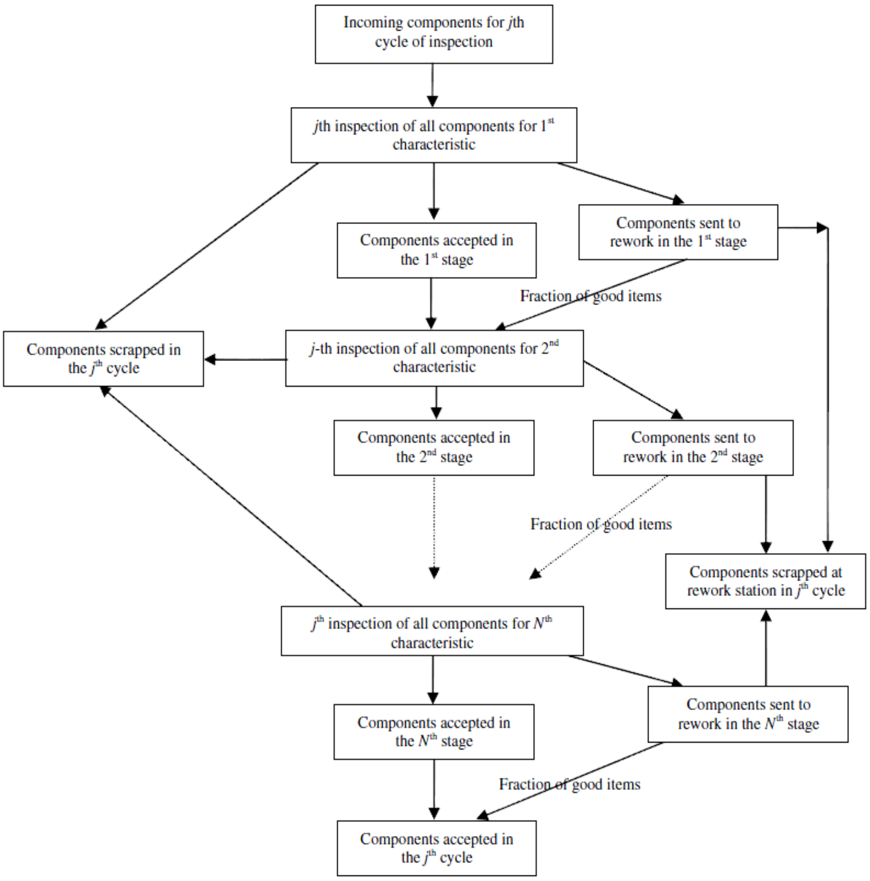

Figure 6: Repeat inspection plan for j^{th} cycle, j= 1,2,…..,n[23].

Duffuaa and Khan [24] came out with the revised model on performance measuring of inspection plan by investigating the impact of different types of inspection errors. The indicators for performance measures were average outgoing quality and average total inspection. Sensitivity analysis was conducted to check the impact of inspection error by using inspection model. Algorithm was developed to determine the optimal values of parameters of inspection plan to minimize the total expected cost. Further, work on repeat inspection plan was done by Elshafei *et al.* [25] to minimize the total cost of inspection per accepted component. An algorithm based on DP was developed to determine the sequence of inspection, number of inspection steps, and number of repeat inspections. Finally, Duffuaa and Khan [26] revised all of the previous research works and provided a general repeat inspection plan for product that have critical components with dependent characteristics. They assumed inspection errors of six types, and came out with a technique for determining the optimum number of cycles that reduced total expected cost, as well. This cost includes cost of false acceptance, cost of false rejection, and cost of inspection.The summary of research work which developed repeat inspection plan for offline inspection under different manufacturing conditions, is given in Table 2.

Table 2: Contribution of the previous research in developing repeat inspection plan.

Authors	Inspection			Penalty cost	Methodology	Study objective
	Plan	Error	Cost			
Duffuaa and Khan [23]	100%	✓	✓	✓	Solution algorithm	Optimal number of repeat inspections plan
Duffuaa and Khan [24]	100%	✓	✓	✓	Solution algorithm	Performance measures of repeat inspection plan
Elshafei *et al.* [25]	100%	✓	✓	✓	DP	Optimal inspection sequence for repeat inspection plan
Duffuaa and Khan [26]	100%	✓	✓	✓	Solution algorithm	Optimal repeat inspection plan for dependent components

3.2. Inspection/disposition policy

Offline inspection has been studied to develop different types of inspection strategies as well as those that include inspection disposition (ID) policy, inspection disposition, and rework (IDR) policy. One of the pioneer work on offline inspection was done by Raz *et al.* [27], in which the problem of economic optimization was solved by determining the ID policy. The objective of their study was to minimize the cost function that includes inspection cost, penalty of incorrect acceptance, and incorrect rejection. Three different policies were investigated: cost minimization policy, perfect information policy, and zero defect policy. Optimal ID policy helped to determine the unit that should be inspected and the order of inspection to minimize the cost. The ID policy of Raz *et al.* [27] was further investigated by other researchers with different assumptions [28-33]. Summary of all the relevant studies is given in Table 3, describing how different authors contributed to development of ID policy and IDR policy for offline inspection.

Table 3: Contribution of the previous research in developing optimal inspection disposition policy.

Authors	Inspection			Methodology	Study objective
	Plan	Error	Cost		
Raz *et al.* [27]	100% and sampling	✓	✓	DP	Optimal IDpolicy
Finkelshtein *et al.* [28]	Sampling	✓	✓	DP	Optimal ID policy
Wang [29]	Sampling	✓	✓	Solution algorithm	Economic ID model
Wang and Hung [30]	Sampling	✓	✓	Solution algorithm	Optimal ID policy
Bendavid and Herer [31]	Sampling	✓	✓	DP& Heuristic policies	Optimal ID policy
Wang *et al.* [32]	Sampling	✓	✓	DP	Economic IDR model
Tsai and Wang [33]	Sampling	✓	✓	DP	ReformulateIDR model

Finkelshtein *et al.* [28] took into account a production process that can be IN state or OUT state but with the ability to recover after a failure. They assumed that only conforming units are produced in the IN state and non-conforming in the Out state. The recursive nature of their problem is briefly explained in Figure 7. The presented ID policy defined which unit should be inspected and how the rest of units should be disposed without inspection. Their objective was to minimize the total cost that includes inspection cost and disposition error cost. An ID policy was also developed for unreliable process where inspection is assumed to be error prone [29]. Thus ID model was modified by considering two types of inspection errors under the following QC policies: cost minimization, zero defects and perfect information policy. Similar extension was done by Wang and Hung [30] in ID policy, but they assumed non-constant failure rate and manufacturing variation in the process. Numerical examples proved that their assumptions have significant effect on cost minimization. However, perfect information policy is infeasible in the presence of manufacturing variation but zero defect policy remains feasible.

Many researchers work on an assumption that confirm units are produced when process is in control state, while non-confirm products are produced when process is out of control state. However, Bendavid and Herer [31] developed the ID policy by assuming that non-conforming units may be produced during the in-control state, and conforming units may be produced during the out-of-control state. Their objective was to developed ID policy for batch production process to minimize the inspection cost and penalty cost due to error in classification. As the computational complexity for optimal ID policy is hugh, four heuristics were developed and compared with optimal policy. One of the heuristic methods gave the best result, but it was complicated to implement and required a long run time.

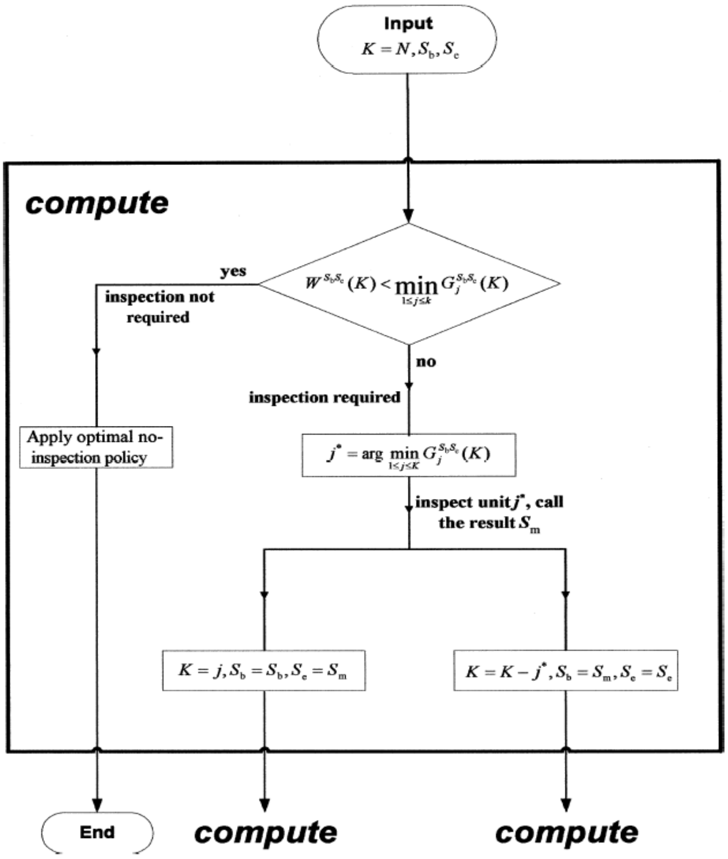

Figure 7: Calculation of optimal inspection/ disposition policy.

On the other hand, Wang *et al.* [32] worked on economic optimization problem of offline inspection by considering the rework and repair of defective products. Thus, IDR model was developed by using DP to generate both the optimal check points and the number of units to be inspected. The results of their model indicated that the added assumptions have significant effect on batch size, expected number of inspections, the FNU, and total expected profit. Meanwhile, Tsai and Wang [33] investigated the flaws present in IDR policy of Wang *et al.* [32] and modified the optimal policy for a batch production system.

3.3. Optimization of process target values

The optimization of process parameters have been kept under investigation since 1950s by many researchers. Pioneer work on process targeting problems was done by Springer [34] and after that number of studies have been conducted in this research area to minimize the expected cost. Previous studies can be divided into two major categories: one that optimize single objective and the other that optimize multi-objectives of offline inspection process. Summary of the published literature done on optimization of process target values is given in Table 4 so as the different assumptions and study objectives, considered by different authors.

Table 4: Contribution of the previous research in optimizing process target value.

Authors	Inspection			Assumptions	Study objective
	Plan	Error	Cost		
Duffuaa and Siddiqui [35]	100%	✓	✓	Inspection is error prone	Optimal process mean and cut off points to maximize the profit
Duffuaa *et al.* [36]	100%		✓	Inspection is error free	Optimal process mean to maximize the profit
Duffuaa *et al.* [37]	Sampling		✓	Inspection is error free	Optimal process mean to maximize the profit
Duffuaa and El-Ga'aly [38]	100%		✓	Inspection is perfect	Maximization of Profit, income, product uniformity
Duffuaa and El-Ga'aly [39]	Sampling		✓	Inspection is perfect	Maximization of Profit, income, product uniformity
Duffuaa and El-Ga'aly [40]	Sampling	✓	✓	Inspection is not perfect	Maximization of Profit, income, product uniformity

In 2000th, a single objective process target model (PTM) was developed for three different types of screening problems [35]. Their objective was to nullify the effect of inspection error by introducing the concept of cut off points. These cut off points acted as decision variables that divide the products into confirm products, grade one, grade two, and scrap. Another PTM was developed to maximize the profit by considering two independent quality characteristics [36]. For this purpose, a two stage process was selected that produced a single product in series. Quality characteristics of a product were determined by the settings of both processes, and 100% inspection was performed to assess its acceptability. The presented model provided a mechanism to determine the optimal values of parameters by assuming that inspection was error free. Similar objective was achieved by modifying this PTM, using acceptance sampling plan [37].

Most recently, multi-objective optimization (MOO) problem of offline inspection system has been investigated to determine the optimal value of process parameters that includes: profit, income, and product uniformity [38-40]. For this purpose, the schematic flow chart of production and inspection process used is shown in Figure 8. The pioneer work on MOO of process target values was done by using 100% inspection policy [38]. Their MMO model optimized the objective functions assuming that 100% inspection was perfect, while an algorithm was also proposed to rank the Pareto optimal points. The MOO model was further revised by changing the inspection policy from 100% to sampling inspection, and similar results were achieved [39]. Further extension in the MOO model was made by assuming that such inspection system, either 100% or sampling, are error prone. Thus two types of inspection errors were assumed and a model was developed to determine the maximum values of the same objective functions. The results of the revised model were compared with the previous models, and it was concluded that inspection error has significant effect on profit and uniformity.

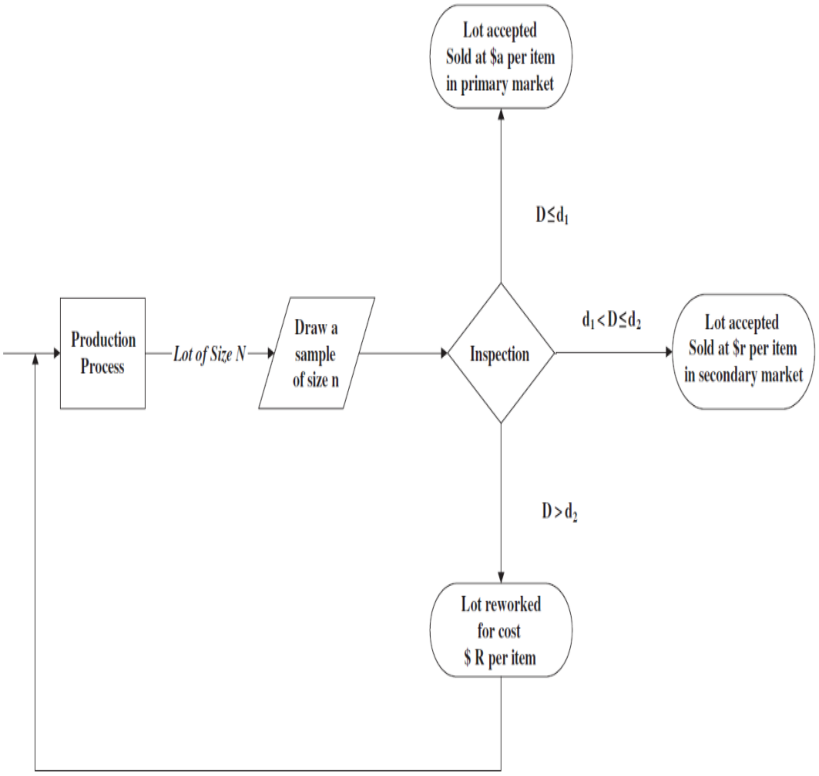

Figure 8: Flow chart of production process for multi-objective optimization model[39].

3.4. Continues sampling plan

Continues sampling plan (CSP) is one of the pioneer inspection method to control the quality of product. This method follows the alternate sequence of screening, i.e. 100% inspection and sampling inspection. This Plan starts with screening process in which each individual product is inspected. Once a given number of products *i* are found confirm, then a sampling process starts, in which only a fraction of products *f* will be inspected. This sampling process will continue until a non-confirm product is found, and the screening will be resumed again [41]. This method of inspection is considered the best for the manufacturing systems where products are made individually in continuous flow, like automobiles, aircraft engines, dell computers, Nike's customers, etc. [42]. Based on the above mentioned two phase inspection system, Dodge [43] developed the simplest sampling plan known as CSP-1. The main objective was to control the quality of a product by monitoring the average outgoing quality level (AOQL). The flow chart showing basic procedure of CSP-1 is given in Figure 9. Much work has been done on this inspection method and a lot of modifications were made in the procedure of CSP-1. The summary of work done is given in Table 5, indicating how different authors contributed to development of CSP for different manufacturing setups. Chen and Chou [44] worked on regret-balanced criteria by considering the consumer's interest and producer's interest of quality for designing the optimal CSP-1 model. Their model determined the best combination of parameters *i* and *f* that maintain the specified value of AOQL, the acceptance quality level (AQL) and the limiting quality level (LQL). The procedure of basic CSP-1 was further modified by Govindaraju and Kandasamy [45] to develop a generalized CSP-C. The advantage of the modified plan is the reduction of the average fraction inspected at a good quality level. For this purpose, the concept of acceptance number was introduced into single level CSP-1.

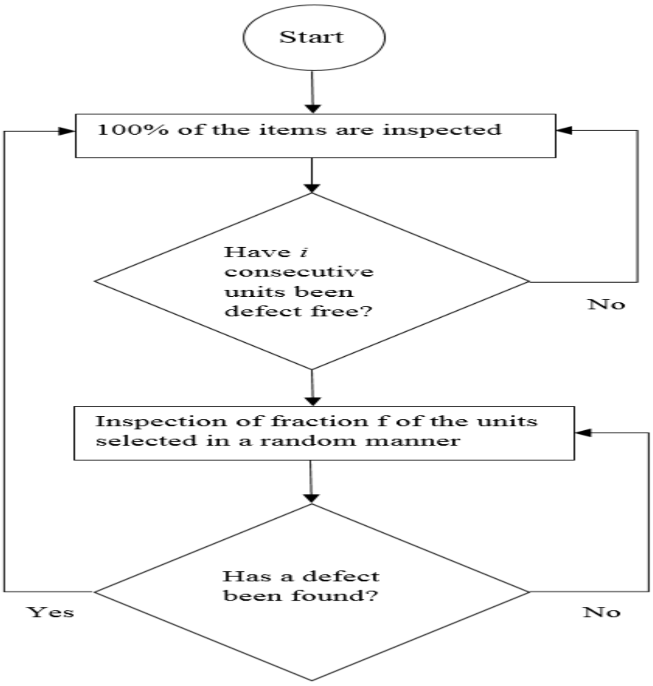

Figure 9: Flow chart of CSP-1[43].

Similarly, cost model of CSP-1 was developed by demonstrating Deming's kp rule [46]. Their model assum that production process has constant proportion of non-confirming products. According to the results, there were no inspection or 100% inspection earns minimum cost per item produced, given that production process was stable. That model was further modified by Chen and Chou [47] in order to develop economic design of CSP-1 under linear inspection cost. Their study assume that inspection cost is linearly proportional to average number of inspections per each inspection cycle. The modified model not only obtained minimum expected cost per unit, but also it maintained the required level of product quality. However, further extension of the model was done under dependent production process along with linear inspection cost [48]. The model describes a solution procedure to determine the best combination of *i* and *f* that maintains AOQL and minimizes the total expected cost per unit during one cycle. Studies are also conducted on CSP-1 for short run production processes. Chen [49] described a method to calculate the AOQL for short run CSP-1 plan based on a numerical method. While in the other study, economic design of CSP-1 was developed for short run CSP-1 plan under linear inspection cost [50]. A solution procedure was presented to determine the optimal value of *i* and *f* that would maintain the target value of AOQL. The optimal results would also minimize the total expected production cost per unit for short run processes.

Table 5: Contribution of the previous research in developing CSP plan.

Authors	Inspection		Penalty cost	Assumptions	Study objective
	Error	cost			
Chen and Chou [44]	✓	✓		Regret-balance criterion	Optimal value of parameters *i* and *f*
Govindaraju and Kandasamy [45]		✓		Concept of acceptance number	Design of generalized CSP-C
Richard Cassady *et al.* [46]	✓	✓	✓	Constant proportion of non-confirm products	Cost model for CSP-1
Chen and Chou [47]	✓	✓		Inspection cost is linearly proportional to number of inspections	Economic design of CSP-1
Chen and Chou [48]	✓	✓		Dependent production process and linear inspection cost	Economic design of CSP-1
Chen [49]		✓		Short run production process	AOQL for short run CSP-1
Chen and Chou [50]		✓		Short run production process under linear inspection cost	Economic design of CSP-1
Lin and Yu [51]	✓	✓	✓	Inspection is not perfect	Optimal policy for CSP-1
Yu *et al.* [52]	✓	✓	✓	In control state shift to out of control state because process may deteriorate	Mixed Inspection policy of CSP-1 and precise inspection
Yu and Yu [53]	✓	✓	✓	Inspection is not perfect and defective product may cause return cost	Joint Inspection policy of CSP-1 and precise inspection
Galindo-Pacheco et al.[54]		✓		Statistical distributions are continuous	Cost minimization of supply chain.
Viswanathan [55]		✓		CSP has three inspections moods	CSP in preventing defects with risk evaluations.
Guayjarernpanishk and Mayureesawan [56]		✓			Modification of CSP-FL to MCSP-FL

Even in recent past, researcher worked on generic CSP-1 plan to enhance its applications with respect to different assumptions. In this regard, Lin and Yu [51] worked on optimal policy of CSP-1 with inspection error and return cost. Optimal values of clearance number *i*, and sampling frequency *f* were determined to reduce the average unit cost. Depending upon the seven parameters, analytical results suggested two optimal inspections policies of CSP-1 that include no inspection or 100% inspection. Yu *et al.*

[52] worked on a mixed inspection policy for precise inspection and CSP-1in order to maximize the unit net profit. Four decision variables were selected that included non-inspected items, and non-defective items, along with optimal clearance number, and sampling frequency. Although the same parameters were considered, analytical results suggested three inspection polices, i.e. no inspection, 100% inspection, and any proportion of non-defective and non-inspected items in CSP-1. Further extension was done to develop a joint inspection policy assuming that each defective item sent to the end customer will be the cause of return cost [53]. The fifth variable of defectives identified by CSP-1 was considered to solve this problem and two inspection plans for CSP-1 were suggested: do not inspect, and do 100% inspection. Conceptual frame work of joint inspection policy developed by Yu and Yu [53]is shown in Figure10.

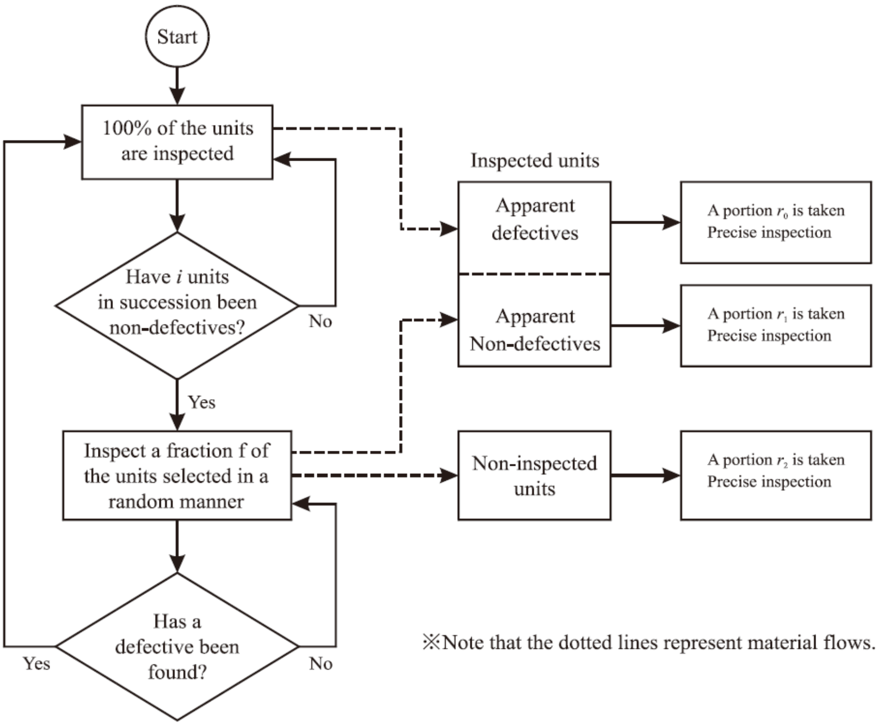

Figure 10: A flow chart of joint inspection policy[53].

In a recent study, another type of continuous sampling plan CSP-2 is explained and implemented along with CSP-1 and lot acceptance sampling plans [54]. Their objective is to minimize the total cost of supply chain, including inspection cost by non-linear programming. CSP was also studied by Viswanathan [55] to prevent the entry of defective produts with risk evaluation by using queuing theory method in produciton and sales system. He presented a probabilistic inspeciton procedure which significantly reduced the inspection cost by decreasing the number of inspections. Recently modified continusous sampling plan (MCSP-FL) was presented for the concept of fractional sampling plan [56]. The perforamnce measures of MCSP-FL and CSP-FL were compared, which included average fraction inspected (AFI), AOQ, and AOQL.

3.5. Multi-stage manufacturing system

Most of the production systems consist of multistage manufacturing stages (MMS). These production systems can be divided into three types: serial production system, assembly production system, and non-serial production system [11]. Today, organizations want to control the quality of their products at different stages of manufacturing as well as achieve required quality level. This requirement encourages the allocation of inspection stations after every major manufacturing process. To get different and effective inspection plans, MMS has also been studied by different researchers. Summary of the literature on MMS published in the years 2000 to 2016 is given in Table 6.

Table 6: Contribution of previous research in developing inspection policy for MMS.

Authors	Inspection			AOQL	Methodology	Study objective
	Plan	Error	Cost			
Heredia-Langner *et al.* [57]	Sampling	✓	✓		Genetic algorithm	Optimal value of sample size and acceptance number
Kakade *et al.* [58]	Sampling	✓	✓		Simulated annealing	Optimization model for selective inspection
Rau and Chu [59]	Sampling	✓	✓		Heuristic solution	Optimal profit model for allocation of inspection stations
Freiesleben [60]	Sampling	✓	✓		Genetic algorithm	Optimal inspection allocation model for inspection systems
Mandroli *et al.* [12]						Survey study on inspection strategy and inspection allocations problems
Van Volsem *et al.* [61]	0, 100% , Sampling		✓	✓	Evolutionary algorithm	Optimal inspection strategy for MMS
Vaghefi and Sarhangian [62]	0, 100% , Sampling		✓	✓	Solution algorithm	Optimal inspection policy for MMS
Shetwan *et al.* [11]			✓		Heuristic algorithm	Review on AQCS in MMS

Heredia-Langner *et al.* [57] worked on a highly constrained multistage partial inspection problem where each stage may receive full inspection or acceptance sampling inspection. Their objective was to maintain good outgoing quality level by determining the optimal value of sample size and acceptance number for each stage. For this purpose, genetic algorithm was used to find out the values of decision variables. Kakade *et al.* [58] also worked on allocation of inspection stations. However, they considered serial manufacturing system for developing optimization model. Their model clearly reflected the economic tradeoff between inspection accuracy and product yield. Their objective was also to minimize the total expected cost that includes inspection cost, repair cost, and penalty cost. For small problems, the results generated by simulated annealing, were close to optimal solutions. While for large problems, optimal solutions were unknown, but significantly better than the initial solutions. Similarly, Rau and Chu [59] also worked on inspection allocation planning of serial production system. However, they considered two types of work stations: workstation of attribute data (WAD), and workstation of variable data (WVD). A highly extensible and applicable profit model was developed for optimal allocation of inspection stations. Heuristic solution method was also presented that took much less time as compared to enumeration method.

Freiesleben [60] worked on cost and benefits of inspection systems and inspection allocation for uniform defect propensity. His main objective was to describe the basic economic principles to use inspection strategies. Comparison of inspection cost with alternative cost of quality improvements was also done. Genetic algorithm was used to solve the allocation problem of inspection station for uniform defect rates. It was concluded that sequential inspection is indeed economically optimal for all except most extreme production cost situations. A survey study was also conducted by Mandroli *et al.* [12] on inspection strategies and sensor distribution studies in discrete-part manufacturing processes. They divided their survey into two major categories: inspection oriented QA strategies and diagnosis oriented sensor distribution strategies. It was concluded that comprehensive work has been done on allocation problem of inspection station, however, plenty of opportunities are still available with sensor distribution problem.

Similarly, Van Volsem *et al.* [61] studied an n-stage manufacturing system to suggest an optimal strategy that gave lowest inspection cost with good quality. Their presented model can be used to decide which inspection type (0%, 100% or sampling) should be executed. Their inspection problem was modeled by using simulation technique. An evolutionary algorithm was applied to find the optimal solution of inspection location, type and inspection limits. A mathematical model was developed by Vaghefi and Sarhangian [62] to optimize the inspection plan for MMS. Their model minimized the inspection cost and assured good quality. To estimate the inspection cost of manufacturing system, they developed their model by using simulation algorithm techniques, and found out the optimal inspection plan. Recently, a literature survey was conducted by Shetwan *et al.* [11] on allocation of quality control station (AQCS) in MMS. The presented approaches and models are reviewed and their solutions techniques are compared. Their review also showed that DP and nonlinear programming are the most common methods used for AQCS, along with integer programming, linear programming, genetic algorithm, and Markovian decision. The general procedure of making decision about inspection or not inspection during MMS is shown in Figure 11 [11].

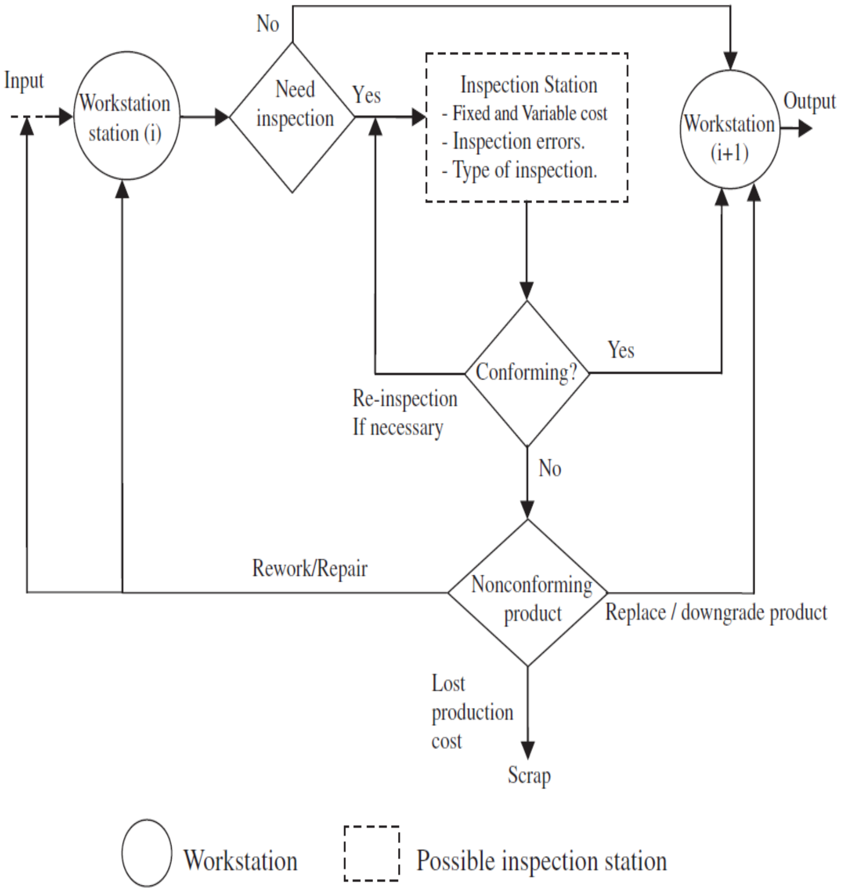

Figure 11: flow chart of inspection station in multistage manufacturing system[11].

3.6. K-IR system

Similar to multi-stage production system, multi-stage inspection systems have also being investigated in recent past. These systems consist of K stage inspection rework (K-IR) system that has interconnected inspection process and rework process. In a complete cycle of K-IR system, finished product is moved from assembly line to the first stage of K-IR system. Confirming products are sent to packing area, while non-confirming products are repaired and moved to the second stage of K-IR system. This process keep on going until required quality of product is achieved. A generalized K- stage process of back light unit is shown in Figure12 [63]. Series of work have been done in the last decade on K-IR system with respect to different assumptions [63-67]. A pioneer K-IR system was developed by Yang [63] to attain a re-specified quality rate at the end of a line. Complete assembly line consisted of a set of K stages process, and each stage included inspection process and a rework process. Assuming two different types of inspection operations, the smallest value of *K* was determined which could achieve target defective rate. Some modifications in K-IR system were done by adjusting different process conditions that includes: time based flow analysis [66], and steady sate flow analysis [65]. In both cases, it was assumed that inspection is perfect and units are not misclassified. The purpose of their studies was to minimize the number of items that need to be inspected. For this purpose, an enumeration method was developed to determine the optimal value of *K*.

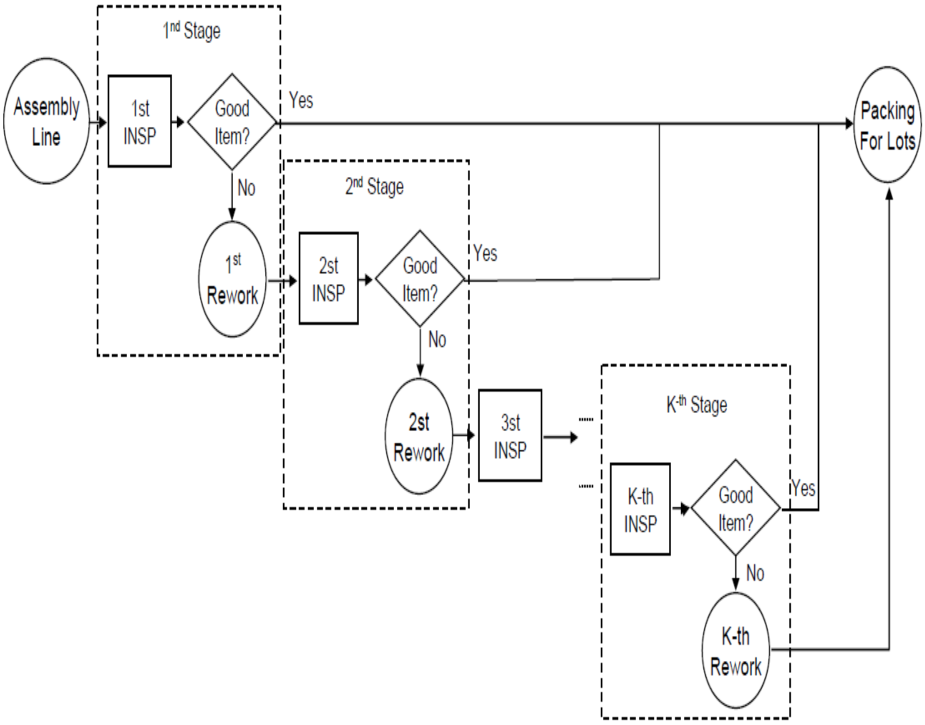

Figure 12: A process flow chart of K stage inspection system[63].

Further, this model was reviewed by considering the effect of lot formation on AOQ so to minimize the inspection cost [64]. Again, an enumeration method was developed to determine the optimal value of K to minimize the required objective function. Recently, K-IR system was extended by Yang and Cho [67]. They assumed imperfect inspection and time-based flow analysis. An optimization problem was addressed in order to reduce the cost related with inspection and rework of K-IR system. An enumeration method was determined to find out the optimal value of K at the end of each assembly line, which minimizes the cost function. Summary of the literature that worked on K-IR system is given in Table 7. It shows the contribution of different authors in this research area.

Table 7: Contribution of the previous research in K stage inspection rework system.

Authors	Inspection			AOQL	Assumptions	Study objective
	Plan	Error	Cost			
Yang [63]	100%	✓	✓	✓	Inspection is imperfect	Optimal value of K to achieve target defect rate
Yang and Kim [65]	Sampling	✓	✓	✓	Steady state flow and inspection is perfect	Optimal value of K to minimize the number of items inspected
Yang and Kim [66]	Sampling	✓	✓	✓	Time based flow and inspection is perfect	Optimal value of K to minimize the number of items inspected
Yang [64]	Sampling	✓	✓	✓	Nonconforming items per lot follows binomial distribution	Optimal value of K to minimize the objective function
Yang and Cho [67]	Sampling	✓	✓		Imperfect inspection & time based flow analysis	Optimal value of K to minimize the cost function

4. CONCLUSIONS

The present literature review objective is to summarize the published literature on offline inspection and to propose future research directions in this field of study. For this purpose, studies conducted on offline inspection were searched from different international journals, published since 2000th to 2016th. The guide lines of systematic literature analysis was used to select the most relevant papers that contributed to the under-study field. Finally, 54 published papers were selected, then divided into six major groups on the basis of their research objectives and inspection strategies. These groups were named as optimal inspection policy, inspection disposition policy, continuous sampling plan, optimization of process target values, multi-stage manufacturing systems, and K stage inspection rework system. The papers published in each group were evaluated separately to highlight their contribution in the research of offline inspection. It is observed that the main objective of all studies on offline inspection was to describe an inspection procedure that can minimize the cost and maintain good quality level, as well. This target is achieved by studying offline inspection of different manufacturing systems with variety of methodologies, and assumptions. Finally, it is concluded that inspection plan, inspection error, inspection sequence, inspection interval, and the number of inspections have a significant effect on the inspection cost and outgoing quality level of the product.

FUTURE RESEARCH DIRECTIONS

Although comprehensive research work has already been done on offline inspection, this review paper propose some future research directions and emerging trends.

1. In the present era, where automations has occupied most of the manufacturing fields and inspection is done by computer controlled machines, there are some industries that still rely on human labor for their manufacturing and inspection processes like textile, clothing, and sports industry etc. Offline inspection with focus on human labor and factors related with human labor is needed to be

investigated [68]. Factors related to human labor include skill level and learning behavior of manpower working in inspection station. Inspection process should be studied by involving process reliability that can be affected by human mistakes [18].

2. Similarly, most of the studies conducted on offline inspection deal with a single product only, and not on manufacturing setups where inspection stations have to deal with different products at the same time. Therefore, inspection of different products under one inspection station should also be studied to investigate the effect of different product types on inspection performance.
3. Some authors talked about the inspection time and proposed that it should be considered when studying the offline inspection[32]. As it can affect significantly the inspection performance, inspection error and inspection cost, either the inspection is human based or automatic [11], thus further studies on offline inspection should incorporate inspection time, in their mathematical models.
4. This review paper shows that different types of optimization techniques were used to achieve optimal results: goal programming, non-linear programming, and dynamic programming. However, comparative study can also be conducted to highlight the difference between the different optimization techniques.
5. Offline inspection policy for non-rigid demand was studied by Anily and Grosfeld-Nir [1], and it was suggested that generalization of production process should be done with increasing failure rate. They suggested that in 100% offline inspection, optimal inspection policy also depends on lot size along with the number of uninspected units and outstanding demand.
6. We also suggest that some work should be done dealing with rigid and non-rigid demand with multiple lots [1]. For rigid demand, two possible actions exist that include “inspect and produce”, while for non-rigid demand the third option is stop production and inspection, and pay shortage cost. Similar work was also suggested by Grosfeld-Nir *et al.* [17] to develop an optimal inspection policy by considering inspection error and unlimited demand.
7. For a batch production process, economic design of offline inspection can also be studied by considering multiple sampling inspection plan [19]. It will help to reduce the total expected cost of inspection. Avinadav and Perlman [19] also suggested that in order to inspect every batch, efficient algorithm should be determined that can find the optimal value of sample size and acceptance number.

REFERENCES

[1] Anily, S., and Grosfeld-Nir, A., "An optimal lot-sizing and offline inspection policy in the case of nonrigid demand", *Operations research,* 54 (2006) 311-323.

[2] Kung-Yung, C., and Yan, T.-M., "The construction of the firm's performance evaluation model on outsourcing activities: Application of the fuzzy synthesis", *Yugoslav Journal of Operations Research,* 20 (2010) 87-97.

[3] Purushothama, B., *Effective implementation of Quality Management Systems,* Woodhead Publishing India, 2010.

[4] Purushothama, B., *A Practical Guide to Quality Management in Spinning,* Woodhead Publishing India, 2011.

[5] Mirkovic, M., Hodolic, J., and Radivojevic, D., "Aggregation for quality management", *Yugoslav Journal of Operations Research,* 16 (2) (2006) 177-188.

[6] Bhowmick, J., and Samanta, G., "Optimal inventory policies for imperfect inventory with price dependent stochastic demand and partially backlogged shortages", *Yugoslav Journal of Operations Research,* 22 (2) (2012) 199-223.

[7] Tzimerman, A., and Herer, Y.T., "Off-line inspections under inspection errors", *IIE Transaction,* 41 (2009) 626-641.

[8] Tirkel, I., and Rabinowitz, G., "The relationship between yield and flow time in a production system under inspection", *International Journal of Production Research,* 50 (2012) 3686-3697.

[9] Tirkel, I., and Rabinowitz, G., "Modeling cost benefit analysis of inspection in a production line", *International Journal of Production Economics,* 147 (2014) 38-45.

[10] Mari, S.I., Lee, Y.H., and Memon, M.S., "Supply chain resilience–a systematic literature review", *Korean society of Industrial Engineering and Management Science,* Proceeding of Joint Conference, *5* (2013) 1789-1797.

[11] Shetwan, A.G., Vitanov, V.I., and Tjahjono, B., "Allocation of quality control stations in multistage manufacturing systems", *Computers & Industrial Engineering,* 60 (2011) 473-484.

[12] Mandroli, S.S., Shrivastava, A.K., and Ding, Y., "A survey of inspection strategy and sensor distribution studies in discrete-part manufacturing processes", *IIE Transactions,* 38 (2006) 309-328.

[13] Colicchia, C., and Strozzi, F., "Supply chain risk management: a new methodology for a systematic literature review", *Supply Chain Management: An International Journal,* 17 (2012) 403-418.

[14] Herer, Y.T., and Raz, T., "Optimal parallel inspection for finding the first nonconforming unit in a batch—an information theoretic approach", *Management Science*, 46 (2000) 845-857.

[15] Grosfeld-Nir, A., Gerchak, Y., and He, Q.-M., "Manufacturing to order with random yield and costly inspection", *Operations research,* 48 (2000) 761-767.

[16] Sheu, S.-H., et al., "Economic optimization of off-line inspection with inspection errors", *Journal of the Operational Research Society,* 54 (2003) 888-895.

[17] Grosfeld-Nir, A., Cohen, E., and Gerchak, Y., "Production to order and off-line inspection when the production process is partially observable", *Naval Research Logistics,* 54 (2007) 845-858.

[18] Wang, C.-H., and Meng, F.-C., "Optimal lot size and offline inspection policy", *Computers & Mathematics with Applications,* 58 (2009) 1921-1929.

[19] Avinadav, T., and Perlman, Y., "Economic design of offline inspections for a batch production process", *International Journal of Production Research,* 51 (2013) 3372-3384.

[20] Aust, G., Bräuer, I., and Buscher, U., "A note on "Quality investment and inspection policy in a supplier-manufacturer supply chain"", *European Journal of Operational Research,* 234 (2014) 910-915.

[21] Balamurali, S., Azam, M., and Aslam, M., "Attribute-Variable Inspection Policy for Lots using Resampling Based on EWMA", *Communications in Statistics-Simulation and Computation,* 45 (2016) 3014-3035.

[22] Sarkar, B., and Saren, S., "Product inspection policy for an imperfect production system with inspection errors and warranty cost", *European Journal of Operational Research,* 248 (1) (2016) 263-271.

[23] Duffuaa, S., and Khan, M., "An optimal repeat inspection plan with several classifications", *Journal of the Operational Research Society,* 53 (2002) 1016-1026.

[24] Duffuaa, S., and Khan, M., "Impact of inspection errors on the performance measures of a general repeat inspection plan", *International Journal of Production Research,* 43 (2005) 4945-4967.

[25] Elshafei, M., Khan, M., and Duffuaa, S., "Repeat inspection planning using dynamic programming", *International Journal of Production Research,* 44 (2006) 257-270.

[26] Duffuaa, S.O., and Khan, M., "A general repeat inspection plan for dependent multicharacteristic critical components", *European Journal of Operational Research,* 191 (2008) 374-385.

[27] Raz, T., Herer, Y.T., and Grosfeld-Nir, A., "Economic optimization of off-line inspection", *IIE Transactions,* 32 (2000) 205-217.

[28] Finkelshtein, A., et al., "Economic optimization of off-line inspection in a process subject to failure and recovery", *IIE Transactions,* 37 (2005) 995-1009.

[29] Wang, C.-H., "Economic off-line quality control strategy with two types of inspection errors", *European Journal of Operational Research,* 179 (2007) 132-147.

[30] Wang, C.-H., and Hung, C.-C., "An offline inspection and disposition model incorporating discrete Weibull distribution and manufacturing variation", *Journal of the Operations Research Society of Japan,* 51 (2008) 155-165.

[31] Bendavid, I., and Herer, Y.T., "Economic optimization of off-line inspection in a process that also produces non-conforming units when in control and conforming units when out of control", *European Journal of Operational Research,* 195 (2009) 139-155.

[32] Wang, W.-Y., et al., "Economic optimization of off-line inspection with rework consideration", *European Journal of Operational Research,* 194 (2009) 807-813.

[33] Tsai, W., and Wang, C.-H., "Economic optimization for an off-line inspection, disposition and rework model", *Computers & Industrial Engineering,* 61 (2011) 891-896.

[34] Springer, C., "A method for determining the most economic position of a process mean", *Industrial Quality Control,* 8 (1951) 36-39.

[35] Duffuaa, S.O., and Siddiqui, A.W., "Process targeting with multi-class screening and measurement error", *International Journal of Production Research,* 41 (2003) 1373-1391.

[36] Duffuaa, S.O., Al-Turki, U.M., and Kolus, A.A., "A process targeting model for a product with two dependent quality characteristics using 100% inspection", *International Journal of Production Research,* 47 (2009a) 1039-1053.

[37] Duffuaa, S., Al-Turki, U., and Kolus, A., "Process-targeting model for a product with two dependent quality characteristics using acceptance sampling plans", *International Journal of Production Research,* 47 (2009b) 4031-4046.

[38] Duffuaa, S.O., and El-Ga'aly, A., "A multi-objective optimization model for process targeting using sampling plans", *Computers & Industrial Engineering,* 64 (2013) 309-317.

[39] Duffuaa, S.O., and El-Ga'aly, A., "A multi-objective optimization model for process targeting using sampling plans", *Computers & Industrial Engineering,* 64 (2013b) 309-317.

[40] Duffuaa, S.O., and El-Ga'aly, A., "Impact of inspection errors on the formulation of a multi-objective optimization process targeting model under inspection sampling plan", *Computers & Industrial Engineering,* 80 (2015) 254-260.

[41] Montgomery, D.C., *Introduction to statistical process control*, John Wiley & Sons, Inc., United States of America., 2009.

[42] Shmueli, G., *Practical Acceptance Sampling: A Hands-On Guide [2nd Edition]*, CreateSpace Independent Publishing Platform, 2011.

[43] Dodge, H.F., "A sampling inspection plan for continuous production", *The Annals of mathematical statistics,* 14 (1943) 264-279.

[44] Chen, C.-H., and Chou, C.-Y., "Design of a CSP-1 plan based on regret-balanced criterion", *Journal of Applied Statistics,* 27 (2000) 697-701.

[45] Govindaraju, K., and Kandasamy, C., "Design of generalized CSP-C continuous sampling plan", *Journal of Applied Statistics,* 27 (2000) 829-841.

[46] Richard Cassady, C., et al., "Demonstrating Deming's kp rule using an economic model of the CSP-1", *Quality engineering,* 12 (2000) 327-334.

[47] Chen, C.-H., and Chou, C.-Y., "Economic design of continuous sampling plan under linear inspection cost", *Journal of Applied Statistics,* 29 (2002) 1003-1009.

[48] Chen, C.H., and Chou, C.Y., "Economic Design of CSP-1 Plan Under the Dependent Production Process and Linear Inspection Cost", *Quality engineering,* 16 (2003) 239-243.

[49] Chen, C.-H., "Average outgoing quality limit for short-run CSP-1 plan", *Tamkang Journal of Science and Engineering,* 8 (2005) 81-85.

[50] Chen, C., and Chou, C., "Economic design of short-run CSP-1 plan under linear inspection cost", *Tamkang Journal of Science and Engineering,* 9 (2006) 19.

[51] Lin, T.-Y., and Yu, H.-F., "An optimal policy for CSP-1 with inspection errors and return cost", *Journal of the Chinese Institute of Industrial Engineers,* 26 (2009) 70-76.

[52] Yu, H.-F., Yu, W.-C., and Wu, W.P., "A mixed inspection policy for CSP-1 and precise inspection under inspection errors and return cost", *Computers & Industrial Engineering,* 57 (2009) 652-659.

[53] Yu, H.-F., and Yu, W.-C., "A Joint Inspection Policy between CSP-1 and Precise Inspection for Non-repairable Products under Inspection Errors and Return Cost", *Journal of Quality,* 18 (2011) 61 - 73.

[54] Galindo-Pacheco, G.M., et al., "Non-linear programming model for cost minimisation in a supply chain, including non-quality and inspection costs", *International Journal of Operational Research*, 14 (2012) 301-323.

[55] Viswanathan, S., "Continuous Sampling Plan in Preventing Defects with Risk Evaluation in Production and Sales System", *International Journal of Computer Applications,* 109 (2015).

[56] Guayjarernpanishk, P., and Mayureesawan, T., "The MCSP-FL Fractional Continuous Sampling Plan", *Thialand Statistician,* 13 (2015) 79-96.

[57] Heredia-Langner, A., Montgomery, D., and Carlyle, W., "Solving a multistage partial inspection problem using genetic algorithms", *International Journal of Production Research,* 40 (2002) 1923-1940.

[58] Kakade, V., Valenzuela, J.F., and Smith, J.S., "An optimization model for selective inspection in serial manufacturing systems", *International Journal of Production Research,* 42 (2004) 3891-3909.

[59] Rau, H., and Chu, Y.-H., "Inspection allocation planning with two types of workstation: WVD and WAD", *The International Journal of Advanced Manufacturing Technology,* 25 (2005) 947-953.

[60] Freiesleben, J., "Costs and benefits of inspection systems and optimal inspection allocation for uniform defect propensity", *International Journal of Quality & Reliability Management,* 23 (2006) 547-563.

[61] Van Volsem, S., Dullaert, W., and Van Landeghem, H., "An Evolutionary Algorithm and discrete event simulation for optimizing inspection strategies for multi-stage processes", *European Journal of Operational Research,* 179 (2007) 621-633.

[62] Vaghefi, A., and Sarhangian, V., "Contribution of simulation to the optimization of inspection plans for multi-stage manufacturing systems", *Computers & Industrial Engineering,* 57 (2009) 1226-1234.

[63] Yang, M., "A design and case study of a K-stage BLU inspection system for achieving a target defective rate", *Management Science and Financial Engineering,* 13 (2007) 141-157.

[64] Yang, M., "Minimization of Inspection Cost in an Inspection System Considering the Effect of Lot Formation on AOQ", *Management Science and Financial Engineering,* 16 (2010) 119-135.

[65] Yang, M., and Kim, S.H., "Minimization of Inspection Cost in a BLU Inspection System Using a Steady-State Flow Analysis", *Management Science and Financial Engineering,* 15 (2009b) 53-68.

[66] Yang, M., and Kim, S.-u., "Minimization of Inspection Cost in an Inspection System Using a Time-based Flow Analysis", *Journal of Korean Institute of Industrial Engineers,* 35 (2009a) 194-202.

[67] Yang, M.H., and Cho, J.H., "Minimisation of inspection and rework cost in a BLU factory considering imperfect inspection", *International Journal of Production Research* 52 (2014) 384 - 396.

[68] Khan, M., Jaber, M.Y., and Ahmad, A.R., "An integrated supply chain model with errors in quality inspection and learning in production", *Omega,* 42 (2014) 16-24.

Appendix I Distribution of studies for different databases

Database	Number of studies
Tayler& Francis	20
Elsevier	15
RASS	3
INFORMS	3
Others	13
Total	54

Appendix II Distribution of studies per journal

Name of Journal	Number of selected studies
International Journal of Production Research	8
European Journal of Operational Research	7
Computers and Industrial Engineering	6
IIE Transactions	3
Management Science and Financial Engineering	3
Journal of Applied Statistics	3
Operations Research	2
Journal of the Operational Research Society	2
Quality Engineering	2
Tamkang Journal of Science and Engineering	2
Management Science	1
Computers and Mathematics with Applications	1
Journal of the Operational Research Society of Japan	1
Journal of Korean Institute of Industrial Engineers	1
Applied Mathematical Modelling	1
Journal of Quality	1
International journal of Operational Research	1
Journal of the Chinese Institute of Industrial Engineers	1
International Journal of Quality& Reliability Management	1
International Journal of Advance Manufacturing Technology	1
Naval Research Logistics	1
Thailand Statistician	1
International Journal of Computer Applications	1
Communications in Statistics - Simulations and computations	1
Total	54