Literature survey about elements of manufacturing shop floor operation key performance indicators

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***Abstract*— In the era of globalisation, manufacturing industries are compelled to continuously monitor their manufacturing operations to maintain competitiveness. As a result, manufacturers have integrated several measurement models to inspect their manufacturing operations. These models comprise of a set of Key Performance Indicators (KPIs), which are capable to enumerate the effectiveness, competence, efficiency and proficiency of manufacturing operations. This paper presents a review of manufacturing shop floor operation KPIs that has been studied in the recent literature. Based on the reviewed literature author proposes various KPI elements such as: description, category, scope, formula, unit of measure, range, trend, mode of display, viewers and manufacturing approach. These elements can help manufacturers to better describe, classify, analyse and measure the appropriate KPIs for their shop floor operations. Thus, enabling manufacturers to accomplish and uphold great quality, increased productivity and throughput.**

***Keywords*— performance enhancement, KPIs, manufacturing operations KPIs and manufacturing industries**

I. INTRODUCTION

The performance of equipment, process, production line or the whole manufacturing industry is principally measured in two ways: result indicators and performance indicators. Result indicators are used to measure the effects of the operations activities but ignoring the cause. While performance indicators are used to generate the next plan of action to be taken based on the results [1]. According to International Standard ISO 22400-1 (2014) [2] and International Standard ISO 22400-2 (2014) [3], KPIs plays a vital role in swiftly and effectively providing precise and detailed statistics of a whole manufacturing industry by equating real-time performance alongside with their nominal performance to accomplish set objectives. A manufacturing industry is composed of a number of operational areas, for instance manufacturing, sales, marketing and many other related functional areas. Based on the operational areas, manufacturing industries can have diverse sets of KPIs [4].

Centred on the operational area, within the manufacturing industries functional hierarchy model: discrete, continuous or batch control of the manufacturing process is at level 1-2 [4]. Whereas, manufacturing operations management is at level 3 and business planning and logistics is at level 4. Figure 1, illustrates the different levels of manufacturing industries hierarchy model. As mentioned in IEC 62264-1 [5], manufacturing shop floor operations can further be categorised into sub operations, such as: production, maintenance, quality, inventory and other manufacturing related operations. KPIs based on each of these sub operations can be defined independently or depending on combinations of these sub operations. In this paper, level 1-3 of the below mentioned hierarchy model, predominantly focusing on manufacturing shop floor operation KPIs is addressed.

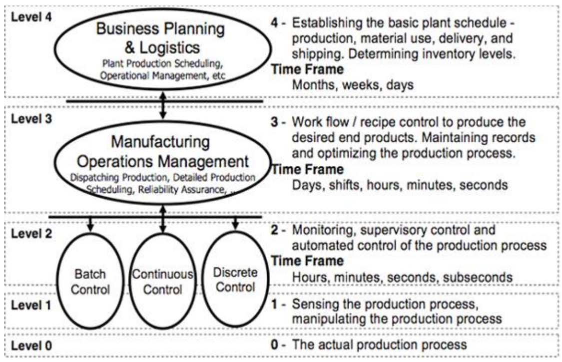

Fig. 1. Functional hierarchy model [5]

Several manufacturing industries that uses KPIs to improve their shop floor operations often detracts from their objectives because they measure numerous KPIs, which leads to fading the emphasis on primary goals [6]. Also, many manufacturers have limited understanding about the right KPIs that can help them to enhance their manufacturing operations [7], [8]. Equally, some of the KPIs have no links related to objectives defined by the manufacturers, and a lot of them monitors one part of process not targeting other imperative processes [9], [10]. In a nutshell, many manufacturers are still struggling to find the required guiding KPI elements to enable design, measure and improve their shop floor performance. Intuiting the difficulties faced by the manufacturing industries, this paper presents a list of KPIs covering all the essentials elements required by a manufacturer before selecting the right KPIs for their manufacturing shop floor operations.

From the set standards on manufacturing KPIs so as to achieve the best industry practices, the key determinants/elements of an ideal KPI should include: description, category, scope, formula, unit of measure, range, trend, mode of display, viewers and manufacturing approach. Some of the manufacturing shop floor KPIs presented in this paper are: allocation ratio (AR), availability (A), corrective maintenance ratio (CMR), cycle time (CT), first time pass yield (FTP yield), mean time to failure (MTTF), mean time to repair (MTTR), overall equipment effectiveness (OEE), performance (P), production effectiveness(PE), production loss ratio (PLR), production process ratio (PPR), quality (Q), rework ratio (RR), scrap ratio (SCR), standard jobs per hour (JPH), setup ratio (STR), technical efficiency (TE), throughput rate (TR), utilization efficiency (UE) and worker efficiency (WE). The rest of the paper is structured as follows: literature review, followed by explaining the elements of KPIs. Then, list of KPIs is presented. Finally, conclusions are drawn.

II. Literature review

To search more on this research area, a meticulous exploration of the literature linked to manufacturing industries shop floor KPIs was conducted over longitudinal basis. This literature review covers materials from the last 20 years. The notion behind setting up this time frame is: during the initial literature search on manufacturing industries shop floor KPIs via google scholar and researchgate, it was seen that this term arouse and gained popularity after the year 1998 (with only 7 publications registered during that year). Followed by 10, 11 and 13 publications in the upcoming years 1999, 2000 and 2001 respectively. The literature was examined by means of the following electronic databases: ABI/INFORM Global, ACM Digital Library, British Standards Online, Engineering Village, IEEE Xplore Digital Library, Science Direct and Scopus. Moreover, University of Warwick library search was also conducted in order to take into account all related books and dissertations.

KPIs plays an important role in assessing the effectiveness and efficiency of any given performance area within manufacturing industries. From the year 1980's, efforts in the manufacturing industries and academia have headed towards achieving high performances in the manufacturing shop floor operations [11]. Research papers, that highlights commonly used manufacturing industries shop floor KPIs are discussed below: Rahman [12], calculated CT to figure out the key downtime causes during total productive maintenance practices in a semi-automated manufacturing company. These downtimes were considered as non-value added undertakings, so minimising these downtimes helped to increase manufacturing performance, and improve the volume of production. Cao et al. [13], Meidan et al. [14] and Wang et al. [15], considered CT vital for multi-objective optimisation in a semiconductor manufacturing industry to reach the set manufacturing targets on time by reducing the downtime. Thus, enabling industries to maintain a competitive advantage in global market. In order to reduce the CT, Bayesian neural model, selective naïve Bayesian classifier and adaptive logistic regression based correlation analysis models respectively, were generated to predict any variations in CT.

Lingam et al. [16], used CT to improve current production rate of t-shirt manufacturing in a textile industry using lean tools. The main focus was to decrease CT using a number of lean tools such as time and motion study, kaizen, failure mode effect analysis and value stream mapping. By doing so, the industry was able to save 82 seconds per product that was 20% reduction in CT, resulting in improved production rate along with increased savings. Ablad [17], worked on optimizing CT and UE in a multi-robot assembly cells. Working with multiple robots often creates collision glitches, which can be minimized by introducing synchronization schemes. These schemes has negative impact on CT and UE, and hence surrogate models were designed that optimises the impact and creates collision free environment inside assembly cells. Lepratti et al. [18], aimed at reducing the dynamic CT in order to deal with highly flexible manufacturing operations in automotive industries. Results proved that reducing dynamic CT by integrating scheduling and sequencing algorithms, improved the manufacturing effectiveness and material handling capabilities.

Kolte et al. [19], implemented effective preventive maintenance scheduling to enhance A, P, Q PLR, PPR and OEE of leading automobile manufacturing industry. Enhancing these KPIs, lead to the increase in continuous productivity and also, attaining higher production rate. This further lead to decrease in the maintenance cost and helped the industry to survive in the highly complex market competition. The case study which was carried on automobile engine cylinder block manufacturing line proved that by implementing the preventive maintenance scheduling: uptime was incremented, MTBF was increased and average MTTR was convincingly reduced. Juaregui Becker et al. [20], developed a new OEE method coined as machining equipment effectiveness (MEE) that focuses on optimising A, P, Q and OEE to improve routing flow, frequency of orders, production time and stability of demands. By taking an example of a high-mix-low-volume manufacturing industry, wherein both the materials and processes are varying, this method was implemented and the results proved to be feasible and effective.

Relkar et al. [21], analysed the OEE of a leading automobile manufacturing company. By determining the performance of a present system, reference values were acquired; and then using regression analysis and various design experiments, ideal equation of OEE was developed. This equation was then used to boost the present OEE, so as to improve the A, P and Q of the company. Roriz et al. [22], demonstrated an industrial case that was concentrated on increasing the Q and OEE of production processes, using single minute exchange of die methodology. By employment of this methodology, the industry was able to efficiently organise their industry shop floor and reduce the setup time. Due to reduction in the setup time, the A of the machines increased and hence production rate significantly improved. Sowmya et al. [23], looked at the capacity problems in manufacturing industries to better A, P and OEE. The main emphasis was to improve utilization of resources and proliferate the performance of present machines using total productive maintenance tools. Similarly, Baluch et al. [24], heightened OEE of a Malaysian palm oil mills using total productive maintenance techniques. As a result there was decrease in overall downtime, improved equipment performance, reduced setup time and improved workers performance.

Meier et al. [25], evaluated KPIs related to planning and delivery of industrial services such as MTBF, UE and WE. This helped manufacturer to efficiently deliver the services by considering and managing these disruptions and uncertainties that causes these delays on-time. Gonzalez et al. [26], listed KPIs (A, MTBF, MTTR, P, RR and TE) covering operation and maintenance phase for efficient wind farm operations. This list was based on the literature review and interviews with stakeholders involved within wind farm operations. It concluded that more in depth revisions are needed within this domain for implementing right KPIs in wind farms operation and maintenance phase. Jovan et al. [27], suggested a method to measure and present the execution of production objectives in the form of introducing production KPIs such as Q, CMR and FTP yield. This KPIs enabled to minimize the production cost and increase the production rate by minimizing downtime and improving product quality.

Stylidis et al. [28], compared the manufacturing quality with the perceived quality and proposed an integrated quality framework that can improve the product quality and benefit customers. Similarly, Jain et al. [29] and Elzahar et al. [30], studied the various quality management systems practices like quality plan, supplier assessments and evaluations, customers satisfactions implemented in manufacturing industries to improve the product quality and benefit customers. Several other papers: used a various prediction methodology for continuous predicting CT, PLR, PPR and PE KPIs in a semiconductor manufacturing industry [30]. Few concentrated on measuring CT, MTTR, MTTF, TR and cycling loss KPIs to assess the impact of total productive maintenance practises on semi-automated manufacturing companies [31]. Few used selective naïve Bayesian classifier for continuous predicting CT in semiconductor manufacturing industry [32]. Heightened KPIs that are used to measure and monitor Q performance in oil and gas industry [33]. Showed how the variation of functional speeds both in material, and manufacturing handling processes leads to dynamic CTs, which enhances the system performance [34].

Chen et al. [35], mentioned the challenges that manufacturing industries are facing in measuring and deciding KPIs for increasing machine performance. Andrej et al. [36], looked after the short-term and long-term production strategic challenges through production KPIs. Garretson et al. [37], concentrated on the terminology that supports manufacturing process characterization and assessment. Borsos et al. [38], explored the relationship between the KPIs and the objectives set by the manufacturing industries in order to determine the waste in the production process. Muhammed et al. [39], cited few manufacturing KPIs and implemented them on multi robot line simulator to improve its performance from the results obtained by the KPIs. Iuga et al. [40], listed few shop floor KPIs for automotive industries based on the interviews conducted with various automotive manufacturers.

Literature review also shows that KPIs are generated mainly based on specific type of industries and only few KPI sets exists based on manufacturing shop floor operations [41]–[45]. Industrial norms for selecting, composing, defining and identifying a required set of KPIs for manufacturing shop floor operations is lacking. Every manufacturer dealing with same shop floor operations has their personalised KPI list that they are interested to evaluate, which are relatively inconsistent. This paper intends to club all these KPIs together with their elements, in order for manufacturers to understand, explore and consider the right KPIs to achieve their desired objectives. By employing the right KPIs industries can achieve increased production efficiency, uniform and high product quality and enhance their throughput. In total, more than 40 KPIs were determined in the above literature. But only 21 KPIs are presented in this paper because these KPIs are sufficient, interrelated and covers the rest of the KPIs. For instance, calculating CT, covers cycling loss as well as cycling gain. CT is a constant value fixed for a machine, station, process or whole manufacturing line. So, values below the fixed CT gives you the cycling gain and values above the fixed CT gives you the cycling loss.

III. Elements of Manufacturing Operation KPIs

These elements are based on the problems highlighted in the literature review as well as considering manufacturing industry best practices. Elements of the KPI can be divided into several sub classes: description, categories, scope, unit of measure, viewers, mode of display, range and manufacturing approach. Table IV lists all symbols with their description used in calculating the KPIs.

A. Description

This section aims for describing the KPI as specific as possible, and must be clearly understood by everyone working in the manufacturing industries. Considering the International Standards ISO 22400-1&2 report [2], [3] and literature review a list of 21 KPIs have been defined, but a more specific definition based on manufacturing industrial operations is required to clearly differentiate them. Hence, table III mentions this KPIs list with a clear manufacturing grounded description.

B. Categories

KPIs are categorised in several ways, subjected to the purpose of use: time, cost, quality, sustainability and flexibility; operations, control, maintenance, planning and inventory; qualitative and quantitative; product, process and resource; inventory, assembly and maintenance. Depending upon the nature of manufacturing shop floor operation and the set objective to be achieved, selecting the right category will be crucial. For example, in a packaging industry, KPIs of interest to operators, and supervisors are time and cost. So, directly monitoring those KPIs will be of interest rather than looking at product or inventory side of KPIs. Furthermore, considering product, process and resource categorisation into account the list of 21 KPIs mentioned in table III can be divided as shown in table I. Similarly, table II categorises the KPIs based on operations, control, maintenance, planning and inventory.

These categories are mainly based on the area of manufacturing shop floor operations. So, readily finding KPIs that are categorized based on the manufacturers demands can help them to employ those sets of KPIs without being concerned about other KPIs. These categorization is done critically based on the literature surveyed. For instance, the research papers that are concentrated on product related KPIs were studied and all the list of KPIs related to this category were mentioned in the product related KPI list. Similarly, all the research papers that are focused on the resource area, were listed in resource category list.

TABLE I. Categorisation of KPIs based on product, process and resource

Product	Process	Resource
FTP yield	A	AR
Q	CMR	PE
RR	CT	PLR
SCR	JPH	PPR
	MTTF	STR
	MTTR	TE
	OEE	TR
	P	WE
		UE

TABLE II. Categorisation of KPIs based on operations, control, maintenance, planning and inventory

Operations	Control	Maintenance	Planning	Inventory
A	FTP yield	CMR	AR	TR
CT	PLR	MTTF	PE	
JPH	PPR	MTTR	STR	
OEE	RR		TE	
P	SCR		UE	
Q			WE	

TABLE III. LIST OF KPIS AND THEIR ELEMENTS

KPI	Description	Scope	Formula	Unit of measure	Range	Trend	Manufacturing Approach	Viewers	Mode of display
Allocation ratio (AR)	It's the ratio between the actual busy times to the actual execution time for any manufacturing operations	Pr, PO, Pl	$\frac{\sum A_{ubt}}{A_{uet}}$	%	0-100 (possibility of more than 100 in case of overlapping operations)	Close to 100	D, C, B	S, M	Pd
Availability (A)	A for a machine, station, process, or whole manufacturing line takes into account all the events that stops planned production	WU	$\frac{T_r}{T_{pd}}$	%	0-100	Close to 100	C, B	S, M	Od, Pd
Corrective maintenance ratio (CMR)	CMR is used to indicate the time that has been spent on corrective tasks on the work unit	WU	$\frac{T_{cm}}{T_{cm} + T_{pm}}$	%	0-100	Close to 0	D, C, B	S, M	Od, Pd
Cycle time (CT)	It is the total time elapsed from the beginning to the end of the process as defined by the manufacturer or user. CT to move a part from one station to another station inside the shop floor is calculated in the given formulae	WU, WC, WO, Pr, Pe	$C_C^y = C_D^{y,S_n} - C_D^{y-1,S_n}$	Time	Once the CT is defined its value remains fixed	The closer to the set value, the better	D, C, B	S, M, O	Rt, Od, Pd
First time pass yield (FTP yield)	It indicates the quality of the order manufactured, and is expressed as the percentage of good products manufactured by the inspected products	WU, Pr, PO, Dt	$\frac{G_p}{I_p}$	%	0-100	Close to 100	D, B	S, M, O	Rt, Od, Pd
Mean time to failure (MTTF)	It is used to indicate the reliability of the given machine, station, process, or whole manufacturing line grounded on the basis of the know failures rates	WU	$\frac{\sum_{i=1}^{T_{fi}} T_{tf}(i)}{T_{fi} + 1}$	Time	Depends on the nature of failure	The higher, the better	D, C, B	S, M	Od, Pd
Mean time to repair (MTTR)	It is used to show how quickly a machine, station, process, or whole manufacturing line can be restored after occurrence of an failure	WU	$\frac{\sum_{i=1}^{T_{tf_i}} T_{tr}(i)}{T_{tf_i} + 1}$	Time	Depends on the nature of failure	The higher, the better	D, C, B	S, M	Od, Pd
Overall equipment effectiveness (OEE)	OEE is multiplication of A, P and Q. It gives the difference between the theoretical calculated production capacity to the actual production capacity of a manufacturing process	WU, P, Dt	$A \times P \times Q$	%	0-100	Close to 100	C, B	S, M	Od, Pd
Performance (P)	P takes into account whatever causes the manufacturing process to operate at less than the maximum possible operating speed. In other words, it shows how efficiently a manufacturing process is performing under the influence of disturbances (slow cycles and small stops).	WU, Pr, Pl, TP	$\frac{T_{cd}}{T_{ad}}$	%	0-100	Close to 100	C, B	S, M, O	Rt, Od, Pd
Production effectiveness (PE)	The ability of the manufacturing system to produce the highest number of good parts (units) by consuming least amount of resources. It helps to find the symmetry between the rate of production and the quality of parts being manufactured.	WU, WC, TP,Pr, Dt, Pl	$\frac{\hat{P}_c * b_{op}}{b_p}$	%	0-100	The higher, the better	D, B	S, M	Od, Pd
Production loss ratio (PLR)	It is used to indicate the amount of quantity lost during production	WU, Dt	$\frac{Q_{lp}}{Q_m}$	%	0-100	The higher, the better	C, B	S, M	Rt, Od, Pd
Production process ratio (PPR)	It is generally used to depict the efficiency of manufacturing production. It is expressed as the ratio of actual production time to the actual order execution time.	Pr, PO, Pl	$\frac{\sum A_{pt}}{A_{oet}}$	%	0-100	Close to 100	D, B, C	S, M	Od, Pd
Quality (Q)	Q is evaluated as the number of good pieces or products produced (pieces that passes quality and inspection test) to the total of pieces produced	WU, WC, Pr, TP, Dt, Pl	$\frac{\rho_p - \rho_d}{\rho_p}$	%	0-100	Close to 100	D, B. C	S, M, O	Od, Pd
Rework ratio (RR)	RR is used to indicate the quality that has not passed the quality and inspection test	WU, Pr, PO, Dt	$\frac{R_Q}{P_Q}$	%	0-100	Close to 0	D, B, C	S, M	Rt, Od, Pd
Scrap ratio (SCR)	It is relationship between the scrap quality and the produced quality	WU, Pr, PO, Dt	$\frac{S_Q}{P_Q}$	%	0-100	Close to 0	D, B, C	S, M	Rt, Od, Pd
Setup ratio (STR)	It identifies the proportion of time used for arrangement or setting up of a system	WU, Pr, PO	$\frac{A_{ust}}{A_{upt}}$	%	0-100	Close to 0	D, B, C	S, M	Od, Pd

	equated to the actual time used for processing								
Standard jobs per hour (JPH)	It is used to indicate the number of jobs executed per hour, against the standards jobs	WU, WC, Pr, Pe, TP	$\frac{3600}{C_{st}} * \text{units per cycle}$	Units/Time	Depends on the type of operation	The closer to the set value, the better	D, B, C	S, M	Od, Pd
Technical efficiency (TE)	It is calculated for a work unit. It is the ratio between actual production time to the actual production time and sum of all the malfunctions and delays that caused disruptions	WU	$\frac{A_{pt}}{A_{pt} + A_{dt}}$	%	0-100	Close to 100	D, B, C	S, M, O	Rt, Od, Pd
Throughput rate (TR)	It is used to indicate the efficiency of the processes; and is expressed in terms of produced quantity of an order to the actual order completion time	Pr, PO, Pl	$\frac{P_q}{A_{oet}}$	Quantity/ Time	Once the TR is defined its value remains fixed	The closer to the set value, the better	D, B	S, M	Od, Pd
Utilization efficiency (UE)	It's an indicator that detects the productivity of the operational work units, and is identified as the ratio between actual manufacturing time to the actual busy time	WU	$\frac{A_{umt}}{A_{ubt}}$	%	0-100	Close to 100	D, B, C	S, M, O	Rt, Od, Pd
Worker efficiency (WE)	It's the ratio between the actual worker operating time to the actual worker attendance time related to the manufacturing orders	W, WG, WU	$\frac{A_{wot}}{A_{wat}}$	%	0-100	Close to 100	D, B, C	S, M	Pd

WU- Work Unit, WC- Work Centre, WO- Work Order, W- Worker, WG- Work Group, Pr- Product, Pe- Personnel, Pl- Plant, PO- Production Order, Dt- Defect types, TP- Time Period, D- Discrete, C- Continuous, B- Batch, S- Supervisor, M- Manager, O- Operator, Rt- Real-time, Od- On-demand, Pd- Periodical

C. *Scope and unit of measure*

In general, scope is used to identify the part for which the KPI is most applicable in the manufacturing industry. For instance, product, worker, work centre (corresponds to production unit, process cell, storage zone or production line), work order or work unit. The unit of measure of KPIs can be anyone of following: rate, ratio, efficiency, utilisation, capability index and effectiveness (refer table III). Based on the formula used to calculate the KPI, the unit of measurement changes. For example, unit of measure to calculate A is ratio. Whereas, unit of measure to calculate MTTR is utilization.

D. *Viewers*

It is imperative to know the viewers for whom the KPIs are being designed. Typically, KPIs are generated for: shop floor workers, supervisors and managers. Based on the type of viewer, the KPI list is designed (refer table III). For example, PE will be helpful for manger and supervisor to make future decisions. While, for the workers PE would produce nothing fruitful.

E. *Mode of display, range and manufacturing approach*

Frequency with which KPIs has to be displayed to generate useful information is vital. For instance, displaying the KPIs for a process, station or the whole manufacturing line depends on the nature of the manufacturing operations. Therefore, KPIs that have severe impact on the manufacturing operations are often displayed in real-time. Typically, KPIs are displayed in: real-time, on-demand or periodically (refer table III). For instance, Q KPI are often displayed on-demand or periodical. Whereas, CT KPI is displayed in real-time, on-demand and periodical.

From the industry best practices, it is recommended that before obtaining the KPI results, one must know the range of the KPI (upper bound and lower bound). Without prior understanding of the KPI outcome, the resulted value would just be a number. So, understanding the range is important in order to enhance the manufacturing performance. Lastly, manufacturing approach identifies the method of manufacturing operation for which the KPI is largely related: discrete, continuous or batch (refer table III).

TABLE IV. LIST OF SYMBOLS USED TO CALCULATE MANUFACTURING SHOP FLOOR KPIS

Symbol	Description
A_{dt}	actual delay time
A_{pt}	actual production time
A_{oet}	actual order execution time
A_{ubt}	actual unit busy time
A_{uet}	actual unit execution time
A_{umt}	actual unit manufacturing time
A_{upt}	actual unit processing time
A_{ust}	actual unit setup time
A_{wot}	actual worker operating time
A_{wat}	actual worker attendance time
b_{op}	overall parts produced in the batch
b_P	amount of time required in producing the batch
C_C^y	CT of part y
C_D^{y,S_n}	departure timestamp of part y at station S_n
C_D^{y-1,S_n}	departure timestamp of part y-1 at station S_n.
C_{st}	standard CT
f_i	failure period end time
G_p	number of good parts
I_p	number of inspected parts
$\hat{P}_c$	predicted cycle-time between the completed parts
P_Q	produced quality
Q_{lp}	quantity lost during production
Q_m	quantity consumed during production
R_Q	rework quality
S_Q	scrap quality
T_{ad}	actual production time
T_{cd}	calculated production time
T_{cm}	total corrective maintenance time
T_{pd}	planned production time
T_{pm}	total planned maintenance time
T_r	run time (machine, station, process, or whole manufacturing line)
T_{tf}	total time in failure
T_{tr}	total time in repair
ρ_p	total production parts
ρ_d	defect parts

IV. CONCLUSIONS

In this paper, a list of manufacturing shop floor operation KPIs were congregated based on the literature review. This literature review covered the most recent research articles and white papers; whose interest was to enhance the performance of manufacturing shop floor operations. Later, few challenges faced by the manufacturers related to selecting the right KPI for their shop floor operations were discussed. A list of KPIs with their detailed elements: such as description, categories, scope, unit of measure, viewers, mode of display, range and manufacturing approach were discussed. This list can help manufacturers to better describe, classify, analyse and measure the appropriate KPIs for their shop floor operations. Because, it clearly states every single details (KPI elements) about manufacturing shop floor KPIs. Thus enabling the manufacturers to accomplish and uphold great quality, increased productivity and throughput, with adequate flexibility, rapid response and negligible downtime. However, the research remains open for further exploration with the purpose of understanding manufacturing shop floor KPIs clearly.

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