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Aspects of Recycling Lithium Batteries

Gaps and Alignments in an Automobile

Highlights

Practical Analysis of the Truck and Bus

Economic, Technical and Environmental

Discovering Thoughts, Inventing Future

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Economic, Technical and Environmental Aspects of Recycling Lithium Batteries: A Literature Review

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Abstract- In the last few years, the automotive industry has been moving towards fuel-free and economically sustainable alternatives, motivated by the latest trends in the market and new regulations about CO_2 emissions. Hybrid and electric vehicles feature a transmission drive with one or more electrical motors powered by Lithium batteries. Thus, Lithium batteries are increasingly used in onboard energy storage systems, leading new economical, technical and environmental challenges which are of fundamental importance in this early stage for the next automotive generation. Recycling materials from used Lithium batteries can also moderate the price of virgin materials, by reducing the price disposal as well as the dependence of manufacturers on exporting countries. Furthermore, recycling Lithium-ion batteries has significant environmental benefits, such as containing the risk of chemical pollution and improving safety in storage facilities for exhausted batteries worldwide. This paper aims to provide a comprehensive insight on Lithium-ion battery recycling for scientific research and industrial applications, examining the economic, technical and environmental aspects of this topic.

Index Terms: automotive engineering; battery recycling; electric vehicle; energy storage; lithium-ion batteries.

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ECONOMICTECHNICALANDENVIRONMENTALASPECTSOFRECYCLINGLITHIUMBATTERIESALITERATUREREVIEW

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Giovanni Filomeno [α] & Stefano Feraco [σ]

Abstract- In the last few years, the automotive industry has been moving towards fuel-free and economically sustainable alternatives, motivated by the latest trends in the market and new regulations about CO_2 emissions. Hybrid and electric vehicles feature a transmission drive with one or more electrical motors powered by Lithium batteries. Thus, Lithium batteries are increasingly used in onboard energy storage systems, leading new economical, technical and environmental challenges which are of fundamental importance in this early stage for the next automotive generation. Recycling materials from used Lithium batteries can also moderate the price of virgin materials, by reducing the price disposal as well as the dependence of manufacturers on exporting countries. Furthermore, recycling Lithium-ion batteries has significant environmental benefits, such as containing the risk of chemical pollution and improving safety in storage facilities for exhausted batteries worldwide. This paper aims to provide a comprehensive insight on Lithium-ion battery recycling for scientific research and industrial applications, examining the economic, technical and environmental aspects of this topic.

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I. Introduction

Since their market entry in the early 1990s, Lithium-ion batteries have become an increasingly important energy storage technology since they feature a very high energy density with respect to other systems. Therefore, they have been widely used in laptops, mobile phones and portable devices [1]. Although Lithium-ion batteries have already been the dominant power source in mobile systems during the past decades, they are experiencing an ever increasing global usage in the automotive industry during the last years to face the recent trends for electric mobility [2]. Moreover, this technology is used as a buffer energy supply to account for the intermittent energy supply from renewable resources in order to match energy supply and demand [2]. Consequently, the public interest in Lithium-ion batteries is growing steadily worldwide [3]. In this framework, electric vehicles featuring one or more electric motors using electricity stored in a Lithium-ion battery are one of the key technologies for the next generation of road transportation, along with novel algorithms for the battery State of Charge (SOC) and State of Health (SOH) monitoring and estimation [4], [5]. However, a wide range of raw materials and industrial processes is required for the manufacturing of Lithium-ion batteries, resulting in supply risks, and a high economic importance of the production chain [6]. Nowadays, the production of raw materials for Lithium-ion batteries is limited to a few regions around the world. This could potentially create availability and price issues [7]. The key materials that have high economic importance but also a high supply-risk are named Critical Raw Materials (CRMs). CRMs include Cobalt (Co), Manganese (Mn), Nickel (Ni), and natural Graphite. Although Lithium (Li) is not currently on the CRM list, its steadily increasing demand could result in supply issues in the very near future [8]. Lithium has a wide range of uses. In 2017, batteries counted on almost half of its use (46%), followed by ceramics and glass (27%), lubricating greases (7%), polymer production (5%), continuous casting mold flux powders (4%), air treatment (2%) and other uses (9%) [8], [9]. Other materials, such as Aluminium and Copper, are also essential in terms of their contribution to the lifecycle environmental impacts of automotive batteries [8]. Therefore, the increasing demand for batteries for electric vehicles and large storage systems may put pressure on the market if combined with sudden changes in the prices of these materials. Potentially this could lead to an interruption of the manufacturing plans for electric vehicles production [7]. Consequently, recycling Lithium-ion batteries to recover useful metals was subjected to European goals from the European Union [10]. Although spent Lithium-ion batteries might be classified as non-environmentally hazardous wastes unlike other batteries containing Cadmium (Cd), Lead (Pb) or Mercury (Hg), the presence of flammable and toxic elements makes their safe disposal a severe issue [11].

Moreover, the N-Methyl-2-pyrrolidone (NMP) commonly used as a solvent for the fabrication of active electrode materials (cathode and anode) has been

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classified as toxic. Therefore this is potentially negative for the environment, causing human exposure to environmental hazards [11]-[13]. Hence, the technical processes of recycling Lithium-ion batteries are of immense importance for waste management sustainability. To this end, both physical and chemical processes are employed in the industry for recycling spent Lithium-ion batteries [11]. Nevertheless, there have not been firm regulations worldwide regarding the recycling of large format Li-ion batteries until now [14]. This might be fine for recyclers, who would initially face no restrictions in process design. However, restrictive regulations could be imposed afterwards. Thus, the recycling processes catered for a specific model or chemistry could become irrelevant in a few years, due to imposed restrictions [14]. The average lifespan of automotive Lithium-ion batteries is usually equal to 3-10 years. After the usage, a large amount of exhausted batteries enters the waste stream period. China, one of the leading countries in the production of Lithium-ion batteries, alone had over 500,000 tons in 2020[15]. As a matter of fact, recycling Lithium-ion batteries reduce energy consumption, as well as it results in 51.3% natural resource savings when compared to landfill [16]-[18]. Furthermore, the main benefit of recycling Lithium-ion batteries lies in avoiding virgin materials extraction from developing countries [16], [19]. However, it is not possible to recycle Lithium-ion batteries without causing any environmental consequences. Thus, a solid discussion on the ecological impact of Lithium-ion batteries recycling processes is still under ongoing research [16], [20].

Considering the framework mentioned above, this paper aims to provide a literature review about the disposal methods and the global impact of recycling a large number of Lithium-ion batteries for electric vehicles that will enter the market in the coming years and will reach the End-of-Life (EOL) in the next decades. Furthermore, the paper focuses on a comprehensive insight into the several perspectives of recycling post-mortem Lithium-ion batteries since the topic needs a multidisciplinary approach, illustrating risks and benefits of Lithium-ion batteries manufacturing and recycling. To that end, Section 2 explains the economic, technical and environmental backgrounds organized in subsections, respectively.

II. Aspects of Recycling Lithium-Ionbatteries

a) Economic Aspects

Cost savings from battery recycling could be in a range of 43% to 90% when compared with a battery entirely made of virgin materials [7][21]. The main elements in a battery (Cobalt, Lithium, Copper, Graphite, Nickel, Aluminium and Manganese) are reported to comprise over 90% of the economic value of a spent Lithium-ion battery: Cobalt (39%), Lithium (16%), Copper (12%), Graphite (10%), Nickel (9%), Aluminium (5%) and Manganese (2%) [21] [22]. These premises lead to the proposal of a circular green economy for Lithium-ion batteries [8], [23], even imposing mandatory recycling rates in the manufacturing process [24].

One of the most critical aspects of the increased demand for batteries can be seen in the price of Cobalt. It rose from 20,000 $/ton in 2001 to 80,000 $/ton in 2017 with an average increase in demand of around 3% per year [25]. After the political situation in Congo was stabilized resulting in a decline of interest from financial speculators, the price fell, and today it is around 29,000 $/ton. Congo has the largest Cobalt mining reserves in the world (3.6 million metric tons in 2019), yet its political situation causes internal conflicts, illegal mining, human rights abuses, and harmful environmental practices.

The same behaviour can be observed for Aluminium. Its price grew from 1,500 $/ton in 2015 to 2,500 $/ton in 2018. After this peak, the price went down to 1,800 $/ton at the end of 2019. Nickel is an exceptional case. Its cost decreased from 29,000 $/ton in 2011 to 7,700 $/ton in 2016. From 2016 to the end of 2019, the price increased up to 18,000 $/ton[26]. Its peak was 50,000 $/ton in 2006. It is reasonable to believe that with increasing demand, its price will increase as it has happened with other materials.

The Lithium price has largely increased between 2016 and 2018[21], going from 80,000 $/ton to 170,000 $/ton. Today however, its cost has drastically decreased, discouraging its recycling [27]. It has even decreased by 14 % since the beginning of 2019due to changing global trading contract.

Regarding graphite, its price has doubled from 2007 to today, going from approximately1000 $/ton to 2500 $/ton.

An even higher increase can be observed for Manganese, its price increasing from 2 $ per Dry Metric Ton Unit (dmtu) to 6.2 $/dmtu with a peak of 8 $/dmtuin 2016 and 2018.

Due to these huge fluctuations in the price of the main components used in battery manufacturing and recycling, the economy related to Lithium-ion batteries might be influenced by both positive and negative aspects. Suffering from wide fluctuations, as in the case of Cobalt, it may not be economically sustainable to recycle the material compared to producing it newly from the mines. The economic possibility will, therefore, be strongly linked to the development of techniques that make recycling more convenient than manufacturing and assembling a new product from virgin material extracted from the Earth's crust. Furthermore, another crucial factor that must be considered for long-term investment is understanding how the automotive market will move. It cannot be excluded, for example, that a different type of battery, such as Lithium-air (Li-air), will enter the market soon or that a different type of propulsion, such as Hydrogen-based power units, will dominate the automotive market in the near future, thus making battery recycling not convenient [28].

b) Technical aspects

The recycling of automotive Lithium-ion batteries to supply production is a long-term strategy which has technical limits. Batteries are expected to have a lifespan of 10 years for propulsion and eventually of 5 to 10 years in a second-life application (i.e. utility) [29]. This means that the set of recycled batteries will not be available before 10-20 years after the mass-market diffusion of electric vehicles. The cooling system plays a fundamental role in the performance and the life of a battery [30] as well as in the performance of the electrical and electronics components [31], [32] which in turn have an influence on the battery life [33]. Furthermore, accurate systems for the estimation of the SOC and SOH could prolong the life of Lithium-ion batteries by avoiding deep discharge and charge cycles at extremely high or cold temperatures, which are one of the major factors that shorten the life of a battery [4],[5]. The efficiency of the battery depends on the collection rate and recycling efficiency. The collection rate is defined as the fraction of collected batteries at their EOL over the total produced Lithium-ion batteries. The recycling efficiency is the ratio of metals and metal components which are recovered from batteries that have reached the EOL [34]. The main constitutive components are listed in Table I [35]. From Table I, it is clear that the production of the cathode, anode and electrode has the central importance in terms of manufacturing processes, but the production of the battery case using plastic materials also has a significant impact. The complete set of materials used in the production of electric vehicle batteries is usually not available from a single manufacturer. A raw composition can be found in literature and is presented in Table II [36] for a Nickel Manganese Cobalt Oxide (NMC) battery and a Lithium Iron Phosphate (LFP) battery.

Table 1: Components of Lithium Battery [30]

Components	Amount (weight %)
Cathode, Anode and Electrode	40 ± 1.5
Plastic case	22 ± 1
Steel case	11 ± 1.5
Copper Foil	9 ± 0.5
Aluminium Foil	6.5 ± 0.5
Electrolyte	5 ± 1
Solvent	5.5 ± 1
Electrical board and circuit	1.5 ± 0.5

Table 2: Materials of Lithium Battery [36]

NMC battery		LFP battery	
Lithium	117 g	Lithium	119 g
Nickel	459 g	Iron	1030 g
Manganese	432 g	Phosphorous	478 g
Cobalt	467 g	Graphite	1,560 g
Graphite	1,626 g		

The main components of a Lithium-ion battery are analyzed in the following.

i. *Cobalt*

The Cobalt contained in the battery cathodes is mainly produced in the Democratic Republic of the Congo (DRC), which supplies 51% of the global cobalt production. The political instability of the region and the strong dependence on this material is currently a severe issue its market price.

Cobalt has an underestimated recycling rate of 16% [37]. Until 2020, the production was able to supply the demand without experiencing difficulties [38]. However, predictions for up to 2050 show that the supply of all existing resources, even at a high recycling rate, will not be enough for the cumulative demand [36]. This requires the market to find new solutions or alternatives.

ii. *Nickel*

Nickel is produced in the Philippines, Russia, Canada and Australia. It is used in high quantity in the cathodes. For instance, it represents 80% of the cathode composition of Tesla vehicles, and the penetration of the electric vehicle in the market of the near future will almost certainly influence the actual price [39]. If electric vehicles are to account for 10% of the global car fleet, the production of Nickel will surely reach 400,000 tons per year [26].

iii. *Aluminium*

Aluminium is used in several parts of electric vehicles such as the car body, battery casing and brake components. It is commercialized in different forms: primary, downstream and secondary Aluminium. The production of the primary Aluminium emits more emissions than secondary (recycled) production. Remolding Aluminium requires only 5% of new production, and this leads to a clear climate benefit [40].Recycling is therefore encouraged by environmental and economic factors, above all for tense relations between China, the world's leading producer, and the West.

iv. *Lithium*

Lithium is the 27th most present element in the lithosphere [34]. As a matter of fact, the estimations on the total quantity of Lithium present in the Earth show 45.2 million tons, and from 12.2 to 14 million tons for global resources and reserves, respectively [36][41].

Lithium is found in different mineral forms and compounds which vary according to the percentage of the element contained. For this reason, the amount of Lithium is evaluated in terms of Lithium metal-equivalent, which represents the amount of element contained in the mineral or compounds.

Lithium resources are mostly located in South America (55%), Asia (17%) and North America (13%). The lithium reserves are located in South America (69%), Asia (17%) and North America (7%) [34]. In South America, the major producers are Argentina, Chile, Bolivia and Brazil. On the other side, China is the principal supplier in Asia, with 12% of the global resources and 17% of the global reserves [6].

More than half of the production in North America is provided by the USA, which has the 8% and 5% of the global resources and reserves respectively [34].

Predictions show that even with the increase of the demand of the electric vehicle, the production rate of Lithium will still be enough until 2050without recycling it. Today, the recycling of Lithium is technically feasible, but the cost is still relatively high. However, the long-term lithium price or political and social changes could force the development of new practices which decrease the costs and make Lithium recycling more feasible [36].

v. *Natural graphite*

Graphite is a common material used for the anode in many battery technologies. It is composed by sheets of carbon atoms which lead to an electrical conducting material. Two types of graphite can be used for this purpose: they are synthetic and natural graphite, which have different price and characteristics.

The synthetic graphite comes from petrochemical processing [42], and it has a pure carbon structure. It leads to high performance, but it is expensive in terms of energy consumptions and costs, which are between 7000 and 20000 $/tons [43]. For this reason, a cheaper alternative has been found in the natural graphite, which has a cost between 6000 and 10000 $/tons for the version with 90-95% of carbon [44]. Most of the reserves are located in Asia, especially in China and India, which have up to 85% of the global resources [45],[46]. The annual production is estimated around 1.6 million tons and 4% is used for batteries [47].

vi. *Manganese*

As with Lithium, the Manganese is largely found in the Earth's crust, and its abundance is around 0.1%. The production is around 16 million tons, and it is used for iron and steel manufacturing [36],[43].The recycling of this material is particularly difficult due to the chemical treatments to be carried out. For this reason, recovery is not yet very developed in Europe, except Germany, and is instead practiced in China, Korea and the Philippines.

vii. *Phosphorous*

Phosphorous has the same abundance of Manganese in the Earth's crust. The phosphate rocks, also called Phosphorite, are estimated around 67 billion tons and 300 billion tons in global reserves and resources, respectively [36]. From this rock, via a reduction chemical process, the metallic phosphorous can be produced. The price for phosphate rock is 3740 $/tons [43].

Considering the complete process of recycling materials from a Lithium-ion battery, it should include a combination of unit operations, in which Lithium and other materials are eventually recovered. Whatever the actual process path in the recycling industry is, it will always be a combination of the following fundamental operations: deactivation, thermal and/or mechanical pre-treatments, hydrometallurgy and/or pyrometallurgy [48],[49]. Complete technical insight on the opportunities, issues and processes of recycling treatments for Lithium-ion batteries can be found in [11], [50], and [51].

c) *Environmental aspects*

The demand for Lithium has grown steadily by 6% per year in the last twenty years [52]. This growth is expected to increase in parallel with the increase in hybrid and electric cars. Considering the increase of the electric vehicles and the availability of materials, it may be noted that there could be a Lithium shortage before 2050 [53]. Nowadays, 70% of its production is in the "ABC" area (Argentina, Bolivia and Chile). Therefore, the increase in demand will produce an expansion of the suppliers. Hence, questions will have to be asked about the environmental and social sustainability of those areas. Also, reserves of Lithium are mostly located in South America, where it can be found in the form of salt. This Lithium salt that is found in the subsoil is dissolved by using copious quantities of water, which is pumped to the surface and then divided from the salt by evaporation. This process also leads to water scarcity problems in regions that are quite poor. Lithium recycling can reduce the load for mining and avoid the emergence of environmental and social problems. Moreover, every material extracted from the Earth is a potential waste, except for metals that are potentially being recycled [54]. Waste from electronic and electrical equipment is one of the fastest-growing waste streams, thus causing an increasing need for disposal areas worldwide [16]. This carries a serious risk of increasing the number of harmful chemicals that can enter the environment [55]. Furthermore, the increasing disposal of portable batteries consisting of various toxic substances could result in disruptive effects for the environment, since their use has almost doubled in the last decade [56]. Although containing fewer quantities of toxic materials than other batteries, a thorough assessment of their recycling process is needed after disposal [17]. The reason for this is that recycling Lithium-ion batteries leads to a reduction of energy consumption, greenhouse gas emissions and natural resource savings with respect to landfill [17][16][18]. Furthermore, avoiding virgin materials production has major benefits for the environment. However, production and recycling of lithium-ion batteries cannot be performed without causing any environmental impacts, as for the high amount of production stages mostly linked with metalworking [19][20].

The Lithium-ion battery production can be mainly divided in the production of the anode, the cathode and the battery pack, because the separator, Lithium salts and solvents have a marginal impact [57]. The battery pack also contains cables and the printed wiring board, which could cause up to 20% of the possible impact on the environment [57]. Copper in the anode is needed as collector foil, and it contributes strongly to the environmental burden of a Lithium-ion battery [57]. Additionally, Copper is also used in the wiring system. Graphite and all other components of the anode only have a marginal impact. The cathode's collector is made of Aluminum foil, and it has an even higher environmental burden in the cathode production chain [57]. The printed wiring board, the process heating and Nitrogen are also important contributors to the total impact of a Lithium-ion battery production, along with the Copper and Aluminum collector foils, Graphite and active materials [57]. Furthermore, the mining and manufacturing processes related to the production of automotive batteries create the largest environmental impact, since the valuable anode and cathode metals can be recycled up to 25%, while total amount of metals recycled is over 47% [35].

Considering the metalworking related to automotive batteries, Chromium and Zinc chemicals, for instance, are used for protective metal plating. However, Zinc is normally contaminated by Cadmium, while Copper mining and smelting are strongly linked with the use of Arsenic, which is both toxic and dissipative, as well as Cadmium which can be found near Zinc refineries. Fortunately, Steel and its alloys, Aluminum and Copper are quite easy to recycle, with a recycling rate up to 45% in the U.S.A.[54]. Nevertheless, many compounds of various metals, such as Arsenic, Cadmium, Copper, Zinc, Lead, Nickel, Chromium, Manganese, Cobalt, Vanadium, Selenium, Tin and Mercury, are toxic to plants and animals. Moreover, salts of Copper, Zinc, Chromium, Tin, Bismuth and Thallium are also toxic to the whole ecosystem. Although many of these metals are recovered for other commercial products, others are almost entirely dissipated or discarded after use [54]. Another point is that the production plants have a major impact on environmental pollution, especially in facilities where environmental controls are weak, as in developing countries. These facilities emit significant amounts of particulates, carbon monoxide, benzene and other aromatics, ammonia and hydrogen sulfide [54]. Aluminium production is performed by means of a polluting process consuming a large amount of lime and caustic soda, generating a caustic waste called "red mud" which is usually left in ponds near the alumina plant. Red mud contains iron. This is useless and corrosive, and it can pollute groundwater, especially in wet climates. Aluminium smelting needs to be performed in remote places mainly to exploit cheap electric power and to minimize the exposure of local populations to fluoride pollution. Electroplating industry also uses toxic heavy metals, such as Chromium and Cadmium, which can end up in the aquifers [54]. Moreover, the rapid growth of this kind of manufacturing in Asia and South America will increase pollution from these sources, which is completely inconsistent with long-term ecological sustainability. For these reasons, it is of fundamental importance to list a serious assessment of environmental impacts of Lithium-ion batteries, imposing the need of closing the materials cycle from extraction to disposal [54] and adopting a green circular economy [58][50]. This fact is crucial for limiting the impact not only of the toxic and non-ferrous metals linked with batteries production, such as Lithium, Cobalt Cadmium, Copper, Mercury, Silver and Zinc, but also ferrous metals, like Chromium and Nickel. Unfortunately, non-ferrous metals are often dispersed in the environment at very low concentrations that make recycling impracticable in most cases.

Furthermore, in the next few years, a huge amount of wasted automotive Lithium-ion batteries will be sent to recycling facilities, introducing novel issues in terms of chemical and industrial safety. Lithium-ion batteries will also require an efficient and safe dismantling phase before treatments, in order to transform current manual procedures in fast, automated systems [59],[50]. Also, several legislations aimed at the management of wasted automotive Lithium-ion batteries will be needed, but there are still some limitations for the industrial treatment due to lack of data sharing, the uncertainty on responsibilities and the unrealistic targets for collection and recycling [50].

III. Conclusion

The rapid growth of electric vehicles will increase the demand on critical materials such as Cobalt, Lithium and Graphite. The consequent growth in demand could lead to potential price increment, with economic consequences which must be strongly assessed. Moreover, the application of Lithium-ion batteries in automotive industry has been growing steadily in the last decade and processes related to Lithium-ion batteries will constitute one of the most important industries in the following years. Nowadays, recycling wasted Lithium-ion batteries is a crucial issue

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to consider, along with improving manufacturing processes, in order to reduce pollution and protect the environment. Moreover, it is fundamental to improve mining and extraction processes both for saving the Earth from global pollution and for reducing hazards for humans. This could be achieved by recycling spent Lithium-ion batteries, and hence minimizing the extraction of raw material from the soil. Therefore, recycling processes should guarantee high recovery efficiency at the lowest environmental impact, allowing primary raw material savings, economic gains, energy consumption reduction, waste minimization and safe management of harmful components. This paper has presented an insight on Lithium-ion battery recycling for scientific research and industrial applications, examining the economic, technical and environmental perspectives of this vast topic.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Giovanni Filomeno conceived the paper and its sections. Stefano Feraco provided most of the literature. All authors wrote the paper and approved the final version.

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Practical Analysis of the Truck and Bus use of Electro-Mechanical Speed Limiter (SLIFA) Device for Fuel Consumption

By Hadi Pranoto, A.M.Leman & Dafit Feriyanto

University Mercu Buana Jakarta

Abstract- The excess speed of trucks and buses is a factor that causes accidents, in addition to the impact on the use of fuel to be wasteful so that operational costs will have a significant effect on fuel needs. In a previous study mentioned several trucks and buses transportation companies. Many install speed limiter that can reduce the potential for accidents by limiting speed, which ultimately has the potential to reduce fuel costs, some of the literature that assembled speed limiter is excessive speed which is directly responsible for the cause of the accident and the level of impact. Reducing speed by 1 km / h can cause a risk of accident 3% less. The frequency of accidents and the death rate increases more than proportionally when the speed increases, other research also discusses the use of fuel in trucks and buses can also reduce CO_2 emissions, the purpose of this study is to improve safety by increasing speed and saving fuel. This research method is to install Speed Limiter Device (SLIFA) on the Truck and Bus engine, which have done by filling the fuel thoroughly to the full with flat road conditions and climbing hills.

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Strictly as per the compliance and regulations of:

Practical Analysis of the Truck and Bus use of Electro-Mechanical Speed Limiter (SLIFA) Device for Fuel Consumption

Hadi Pranoto [α], A.M.Leman [σ] & Dafit Feriyanto [ρ]

Abstract- The excess speed of trucks and buses is a factor that causes accidents, in addition to the impact on the use of fuel to be wasteful so that operational costs will have a significant effect on fuel needs. In a previous study mentioned several trucks and buses transportation companies. Many install speed limiter that can reduce the potential for accidents by limiting speed, which ultimately has the potential to reduce fuel costs, some of the literature that assembled speed limiter is excessive speed which is directly responsible for the cause of the accident and the level of impact. Reducing speed by 1 km / h can cause a risk of accident 3% less. The frequency of accidents and the death rate increases more than proportionally when the speed increases, other research also discusses the use of fuel in trucks and buses can also reduce CO_2 emissions, the purpose of this study is to improve safety by increasing speed and saving fuel. This research method is to install Speed Limiter Device (SLIFA) on the Truck and Bus engine, which have done by filling the fuel thoroughly to the full with flat road conditions and climbing hills. The results of this study indicate the level of fuel consumption compared to the standard, from the total test mileage (km) to the overall flat test distance 138.8 with a fuel consumption ratio of 1:3,12, then on the hill climbing test as far as 123.6 km, with a ratio of 1: 2.19 (ltr/km), from the results of this test, when compared to the fuel consumption standard on the type of truck and bus are 1:2,5 (ltr/km) on flat road conditions and 1.19 on hill climb conditions, then increased fuel consumption by installing speed limiter in truck and bus engines is there a fuel savings of up to 26%, this can change according to the characteristics of the driver in operating it.

I. Introduction

Fuel is the highest variable cost in the management of operations management in the transportation sector, and another thing is the safety factor becomes the top priority in the continuity of the transportation business [1]. Some truck and bus transportation companies, many install speed limiter that can reduce potential accident by limiting speed, which in the end has the potential to reduce fuel costs, some of the literature assembled speed limiter is excessive speed directly responsibility for the cause of accidents and the impact level [2]. Reducing speed with 1 km/h could lead to a 3% fewer accident risk. Accident frequencies and fatality rates increase more than proportionally when speed levels increase [3], especially when a specific speed limit exceeds. Speed reduction is not only to the benefit of road safety but can also reduce fuel consumption and CO2 emissions [4]. The relation between speed and safety rests on two pillars. The first pillar is the relation between collision speed and the severity of a crash.The second pillar is the relation between speed and the risk of a crash. The higher the collision speed, the more serious the consequences in terms of injury and material damage [5]. The purpose of speed limiter is to control the fuel feed into the engine to push the vehicle speed to appropriate speed, which frees up the speed of the vehicle by turning off quickly to reduce the rate of fuel delivery into the engine combustion chamber, when the fuel stops and the breaker relay connects to the accelerator pedal when that speed will decrease gradually if the driver presses the pedal back to the specified limit in the controller motor that mounts on the injection pump [6]. The primary principle function of speed limiter shown in Figure 1.

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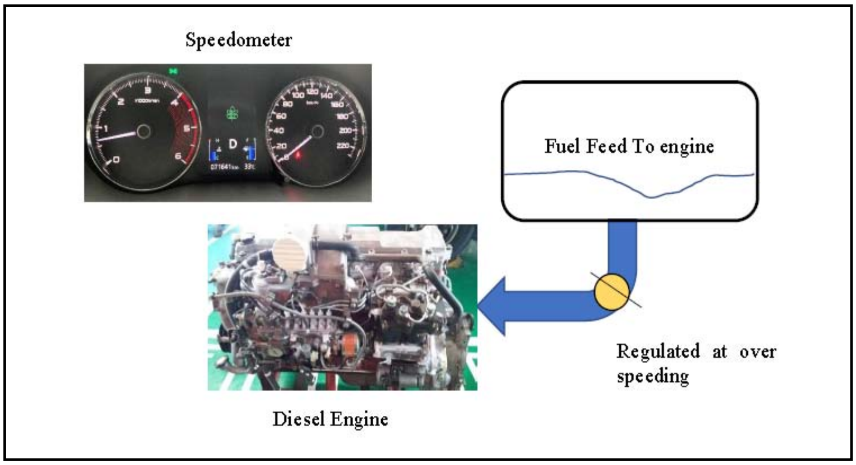

Fig. 1: The function of speed limiter [6]

Speed limiter types based on control technique;

According to Gawad and Mandourah, (2015), there are several types of speed limiter on controlling the vehicle speed. It depends on the adopted technologies. The control techniques such as accelerator control, cable types a motor will control the stroke length of the accelerator pedal linkage to the fuel pump, by attaching the control cable held by the fuel breaker solenoid, the fuel delivery termination will stop very quickly, and this control technique is easy to install because it is only limited to a mechanical system, which can connect to gasoline-based engines or diesel engines, electronic pedal control and direct fuel control (solenoid valve type). The fuel relay engine cut-off for a moment when the speed exceeds the specified limit by adjusting the fuel engine cut-off motor attached to the fuel throttle, when the driver presses the accelerator pedal to be full and will not change the speed that has been set, that's when the limitation is speed on the vehicle can be achieved.

The survey conducted by the American Transport Research Institute (ATRI) in 2008 consisted of 27 multiple choice questions and was design for 10 minutes of completion time. Primary data collection questions, such as fleet size and type of operation. If the fleet does not use a speed limiter, the respondent is asked to choose one or several reasons because it is underused and does not ask further questions. If the fleet uses speed limiting, the respondent asks about speed limiting in terms of fuel economy perception, fleet safety, driver acceptance, vehicle operations, and related problems [7]. General comments and suggestions, the respondents believe that all information provided will be kept confidential. About 1,500 surveys were approved by e-mail, and 103 were received, the response rate was obtained around 7%. Study-related to fuel economy using a speed limiter, complete, is provided, as shown in Table 1. And Figure 1.

Table 1: The satisfaction of using a Speed Limiter [7]

	Very Successful	Successful	Neutral	Unsuccessful	Very Unsuccessful	Cannot Determine
%	35,7%	40,4%	17,9%	2,4%	0,0%	3,6%
N	30	34	15	2	0	3

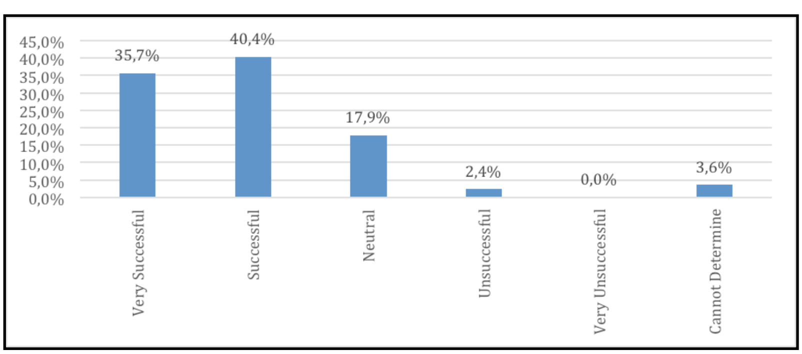

Fig. 2: Satisfaction chart of using a Speed Limiter

II. Methodology

To achieve the purpose of this research, we propose a methodology in Figure 1, and the method consists of the steps of how we install speed limiter SLIFA device on the Truck and Bus.

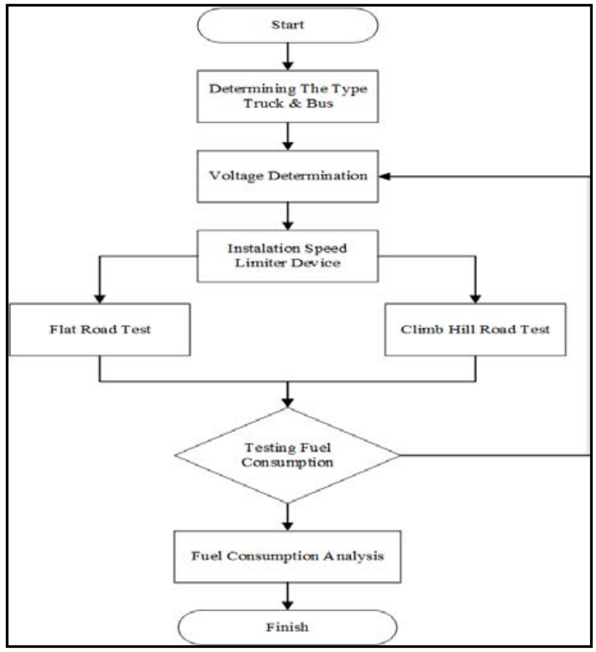

Fig. 3: The Proposed Methodology

Truck and Bus Engine Specifications

The following is the specification of the truck and bus engine installed with a speed limiter device, and this specification standard [8], will be compared when it is connected with a speed limiter device to determine the level of fuel consumption savings.

Table 2: Engine Specifications [8]

Engine	Diesel Engine 4 Stroke Inline Direct Injection 6 cylinder with Turbo Charger Intercooler and Common Rail Mechanism. Power maximum 285/2500 (PS/rpm) Torque maximum 91/1500 (Kg/rpm) Fuel Consumption 1: 2.5 (ltr/km)
Performance	Maximum speed 105 km/hr and Gradebility 34 (tan%)

In the determination of speed reduction, the speed limiter was divided by inputs frequency value from the speed sensor (a). The speed obtained directly sends a voltage change component, The frequency changes to that voltage are used to provide a trigger to the string that attaches to the position on the side of the engine on the accelerator pedal (b). Each of these inputs served as a trigger to reduce the speed 60 km/h or 70km/h.

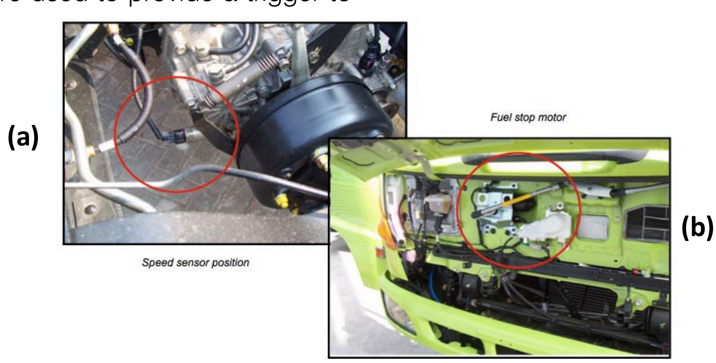

Fig. 4: Voltage Determination

All restrictions of each velocity based on V*in* and V*max* value [9]; the formula for calculating the expected output voltage is in Equation 1.1.

$$\text{Vout} = \text{Vcc x f x } C_1 \text{ x } R_1 \qquad (1.1)$$

Installation Speed Limiter on the Truck and Bus

The installation procedure of SLIFA to the vehicle shown in Figure. Generally, there are three wires that need to be connected to the SLIFA device, which is the signal wire from engine speed, fuel cut off solenoid wire, and ECU wire.

SLIFA installation procedure, as shown in the schematic circuit Figure 2, was performed using the following steps:

1. For diesel trucks and buses, the device was connected to the cable on-brakes of the fuel system as once installed, the existing engine stopped the original motor.
2. After the first point made, it was connected with a cable to the box SLIFA to the process in an electronic circuit and forwarded to the speed sensor on the transmission output.
3. The data pulse from the speed sensor was sent to the speed sensor back and connected to the motor engine stop relay.

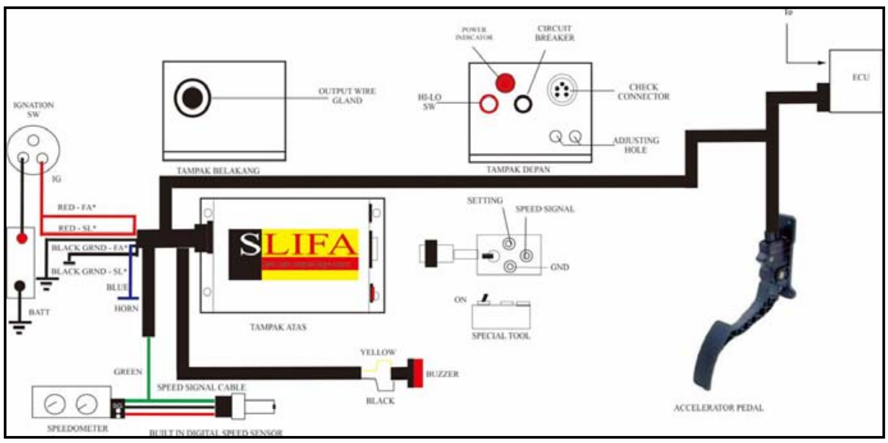

Fig. 2: Schematic SLIFA Installation [9]

Installation Digital flow meter

Comparison between truck and bus installed and uninstalled (base on standard) by speed limiter performed to investigate the effect of Speed limiter device on fuel consumption, the purpose of this test is how the device and a positive impact other than safety is fuel economy, so this will be able to help the industry in terms of operational efficiency. The digital flowmeter was installed in a high-pressure flexible pipe at the fuel injection pump to monitor fuel flow during driving with various driver characteristics drivers when running the vehicle. The digital flow meter monitoring system shown in Figure 3.

Fig. 3: Digital Flow Meter for Diesel Engine

The fuel will return to the storage tank through a valve over flow. The error increased when more fuel was returned to the tank (when less fuel was burned by the engine)[10]. The worst-case accuracy for any supply to return rate reading combination can be determined by using the following equation 1.2 :

Maximum Error = [(0.5% x Supply rate) + (0.5% x Return Fuel)]/ Burn rate (1.2)

III. Result and Discussion

Route Test

After installing the speed limiting device and after testing the laboratory scale, they are then checking the laboratory scale with actual environmental requirements, namely by conducting direct tests on the highway with a distance of 138 km with average road conditions or normal road conditions, following the results of the data fuel consumption testing.

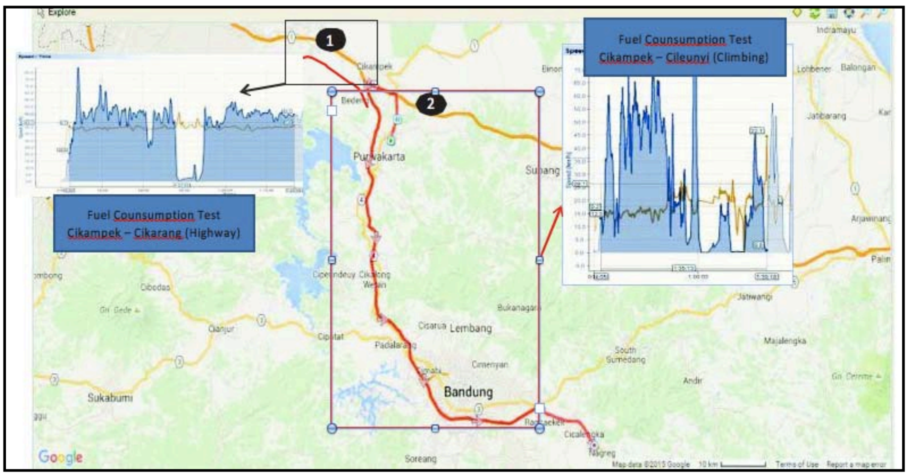

Fig. 4: Route Test Fuel Consumptions

The test route, as shown in Figure 2, point 1, the maximum speed of the compilation to do the test is 60 km /hr, then many highways on the toll road and in normal road conditions with the degree of great ability do not exceed 9°.

Flat Road Fuel Consumption Test

When the flat road test conducted, the speed limiter set to the initial speed limit with a maximum of 60 km/hour by regulations that have been fixed by the Republic Indonesian government through land transportation minister regulation No: 111 of 2015.

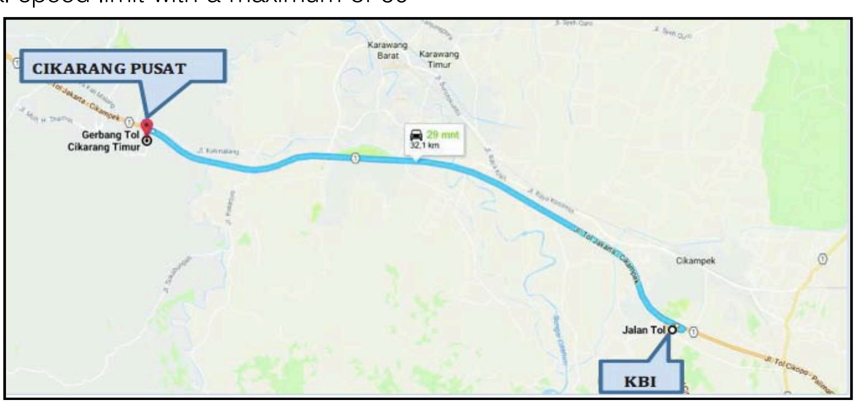

Fig. 5: Route Flat Road Fuel Consumption Test

From the flat road test results data with the total distance of testing in the toll road area with the length of the test path carried out and with a total of 4 trips usual trip, each trip 34 km with a total of 138.8 km. from the testing shows a very significant fuel consumption reduction from the standard fuel consumption that has been issued by APM on these types and units. The results of the test seen in Table 2 and Figure 4.

Table 2: Flat Road Fuel Consumption Test

No.	Route	SG 285 TH		
		Trip	Fuel Consumption (L)	Ratio(ltr/km)
1	KBI ~ Cikarang Pusat	34,6	9,547	1:3.62
2	Cikarang Pusat ~ KBI	34,8	11,3944	1:3.05
3	KBI ~ Cikarang Pusat	34,6	11,6918	1:2.96
4	Cikarang Pusat ~ KBI	34,8	11,8273	1:2.94
	Total	138,8	44,4605	
Ratio Total Fuel Consumption			1:3.12	

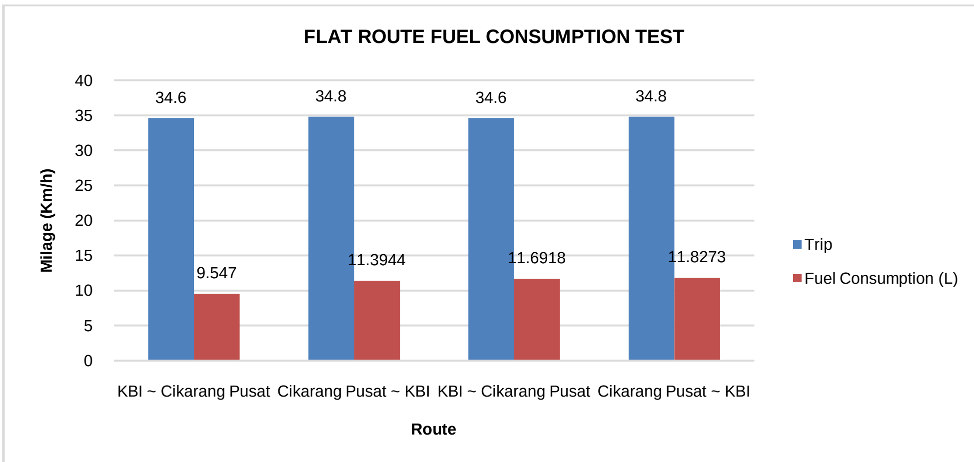

Fig. 6: Route Flat Road Fuel Consumption Test

From Table 2 and Figure 6 flat road test shows that fuel consumption 1:3,12 ltr/km is composed of 1 liter of fuel for trucks and buses with type the engine Table 2, able to work with a distance of 3,12 km with an average speed of 60 km/hour, then if compared to the specifications of the APM can save fuel as far as 1 km with the percentage of effectiveness 80% of the standard value of fuel consumption.

Hill Climb Road Fuel Consumptions Test

This test was carried out with a distance of 123.6 km with quite an extreme operation because almost all road conditions that were pass were mountains with grad ability reaching 10 °, when testing the maximum speed was only 50 km/hour and the rpm was quite high with average conditions 1800 up to 2500 rpm.

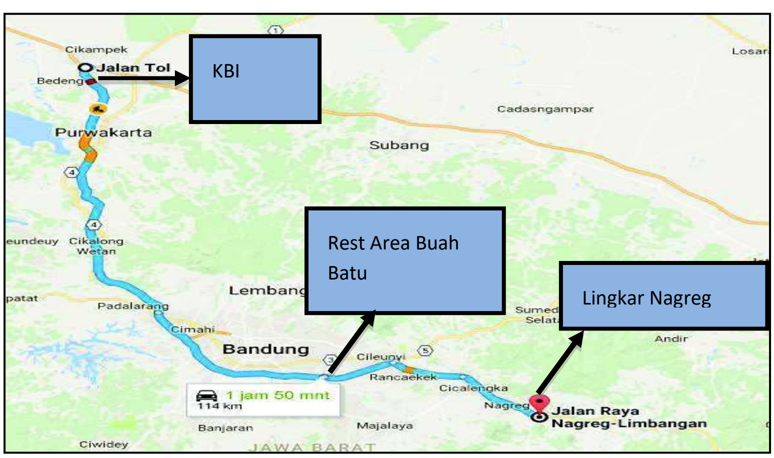

Fig. 7: Route Hill Climb Fuel Consumption Test

From the test data as shown in Table 3 and Figure 7, fuel consumption in this condition is more wasteful, due to the compilation of 10 ° uphill road conditions requires higher engine run (rpm) compared to the flat ones, from the test results obtained fuel consumption data climbing conditions uphill is 1: 2.19 ltr / km.

Table 3: Hill Climb Road Fuel Consumption Test

No.	Route	SG 285 TH		
		Trip	Fuel Consumption (ltr)	Ratio (ltr/km)
1	KBI ~ Buah Batu (High way)	91,4	42,308	1:2.16
2	Buah Batu ~ Lingkar Nagrek (General road & High way)	32,2	14,223	1:2.26
	Total	123,6	56,5308	
	Ratio Total Fuel Consumption		1:2.19	

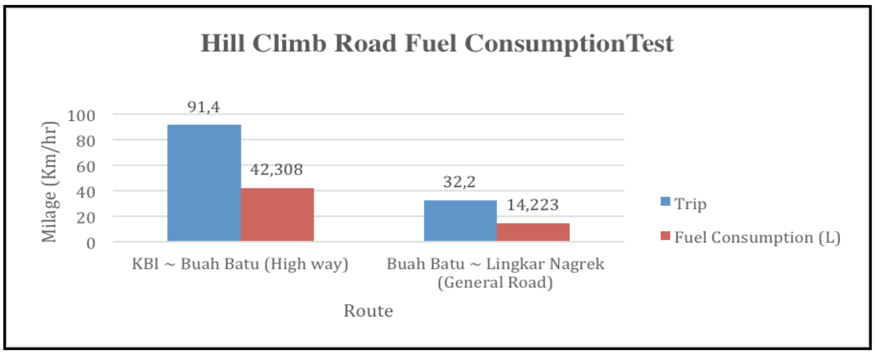

Fig. 8: Route Hill Climb Road Fuel Consumption Test

IV. Conclusion

The results of this study indicate the level of fuel consumption compared to the standard, from the total test mileage (km) to the overall flat test distance 138.8 with a fuel consumption ratio of 1:3,12, then on the hill climb test as far as 123.6 km, with a ratio of 1: 2.19 (ltr/km), from the results of this test, when compared to the fuel consumption standard on the type of truck and bus are 1:2,5 (ltr/km) on flat road conditions and 1.19 on hill climb conditions, then increased fuel consumption by installing speed limiter in truck and bus engines is there a fuel savings of up to 26%, this can change according to the characteristics of the driver in operating it. Then if compared to the specifications of the APM can save fuel as far as 1 km, with the percentage of effectiveness, 80% of the standard value of fuel consumption. The installation of speed limiter devices on truck and bus engines not only for saving fuel but also providing better safety quality and impact the sustainability of the transportation business. With the consumption of fuel-efficient, emissions from combustion may be better, although this needs further research.

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Rework Reduction of Gaps and Alignments in an Automobile Assembly Plant

By Anand Umrani & Harshvardhan Uttarwar
Vishwakarma Institute of Technology

Abstract- India is one of the fastest growing hubs for auto manufacturing industry. Most of the global auto manufacturing leaders are moving towards Indian market. In this study, the productivity of an automobile assembly plant XYZ is improved by implementing lean techniques and IE tools. The focus of this study is tackling a frequent problem of nonconforming gaps and alignments in a particular car model assembled in the plant. This paper explains the methodology implemented to reduce cycle time as well as rework caused by nonconforming gaps in a detailed manner.

Keywords: root cause analysis, gaps, alignments, cause effect, graphical analysis.

GJRE-B Classification: FOR Code: 090299

REWORKREDUCTIONOFGAPSANDALIGNMENTSINANAUTOMOBILEASSEMBLYPLANT

Rework Reduction of Gaps and Alignments in an Automobile Assembly Plant

Anand Umrani [α] & Harshvardhan Uttarwar [σ]

Abstract- India is one of the fastest growing hubs for auto manufacturing industry. Most of the global auto manufacturing leaders are moving towards Indian market. In this study, the productivity of an automobile assembly plant XYZ is improved by implementing lean techniques and IE tools. The focus of this study is tackling a frequent problem of nonconforming gaps and alignments in a particular car model assembled in the plant. This paper explains the methodology implemented to reduce cycle time as well as rework caused by nonconforming gaps in a detailed manner.

Keywords: root cause analysis, gaps, alignments, cause effect, graphical analysis.

I. Introduction

The XYZ assembly plant consisted of four major production units namely Body shop, Paint shop, Assembly line and Finish line. Body shop, Assembly line and Finish line each has a quality-check workstation at the end of their respective lines. Nonconformity of gaps and alignments, of a certain car model assembled in the plant was observed frequently. This nonconformity to standards resulted in excess rework after the quality-check of Assembly line. The workstation where these gaps and alignments were set acted as a bottleneck for the entire assembly line (because operators of this workstation were required for heavy rework frequently) which in turn affected the productivity of the entire plant. Process standardization was required along with verification of Body shop and Assembly line standards for gaps and alignments. The cause of excess variation in dimensions wastobe identified.

II. Preliminary Analysis

a) Root Cause Analysis

Defined problem was rejection of cars due to measure of gaps and alignments present not conforming with the allowed specifications. Checkpoints between 'door and fender' of the car were identified to be in the crash zone and 100% cars were affected by this problem. Location of the problem was identified to be the workstation of Assembly line where gaps and alignments were set. For future reference, the workstation will be named – Station 18.

b) Cause Effect Diagram

The cause effect diagram revealed that the operator checking process for gaps and alignment was improper and could be a potential cause of excess variation. Another plausible cause identified was irregular recalibration of filler gauges rendering them to show incorrect values of gaps.

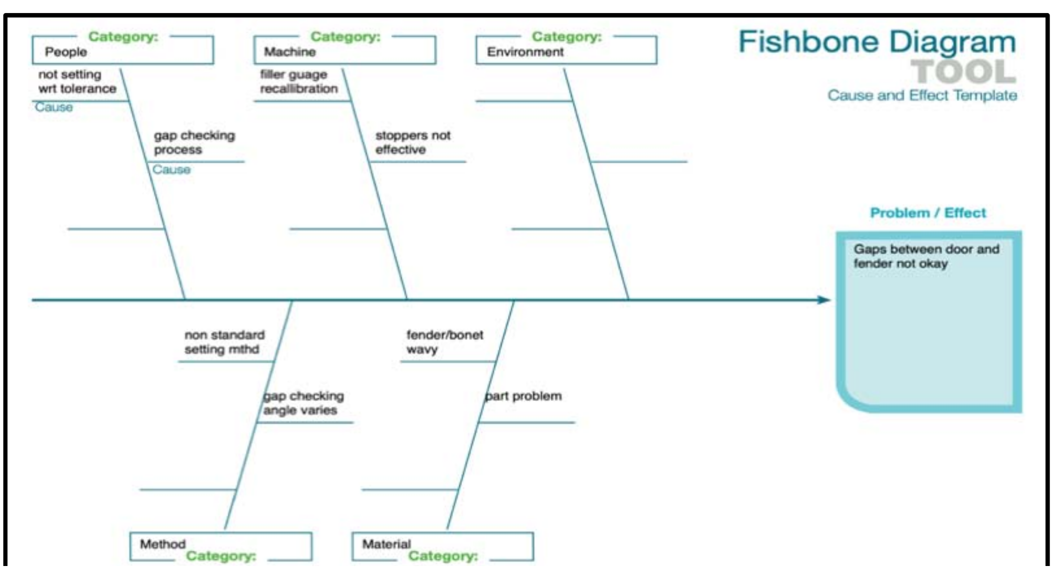

Figure 1: Cause Effect Diagram

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III. Methodology

Four major tasks were implemented to tackle this issue. These tasks included identification of missing checkpoints in Body shop, collecting data for four important checkpoints at four different stages and plotting graphs.

a) Identifying missing checkpoints for gaps and alignments

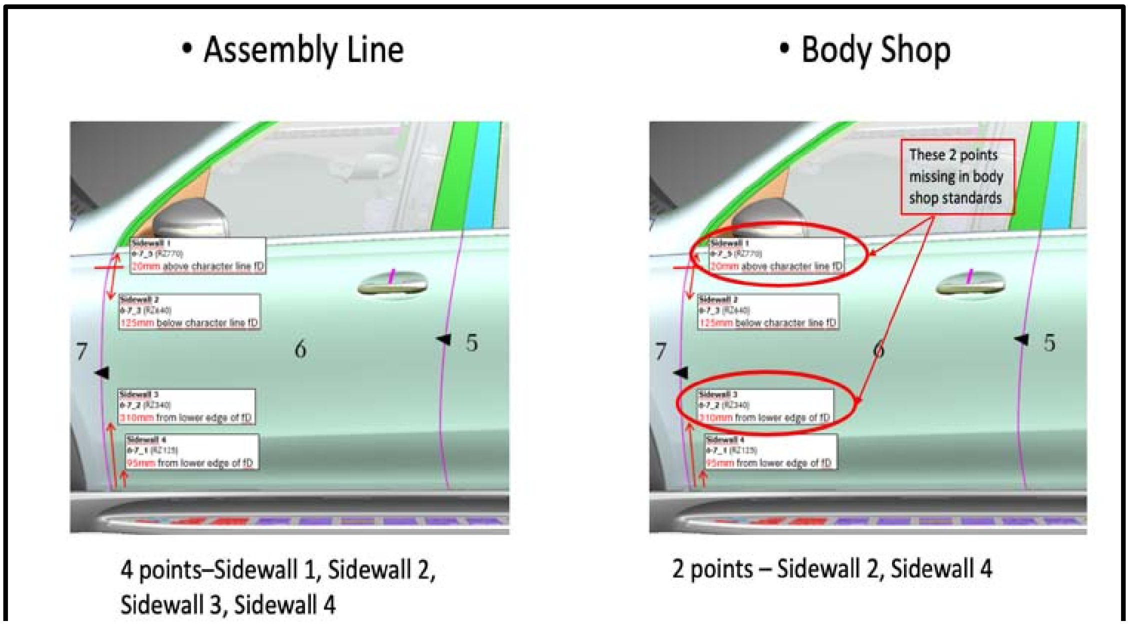

Figure 2: Door to Fender Checkpoints

The two checkpoints between door and fender of the car, highlighted in the figure are not checked at the Body shop quality-check workstation. Since Body shop operators do not put any kind of effort to bring these points in specified tolerance limits, it takes much more time for Assembly line operators to adjust the gaps at these checkpoints.

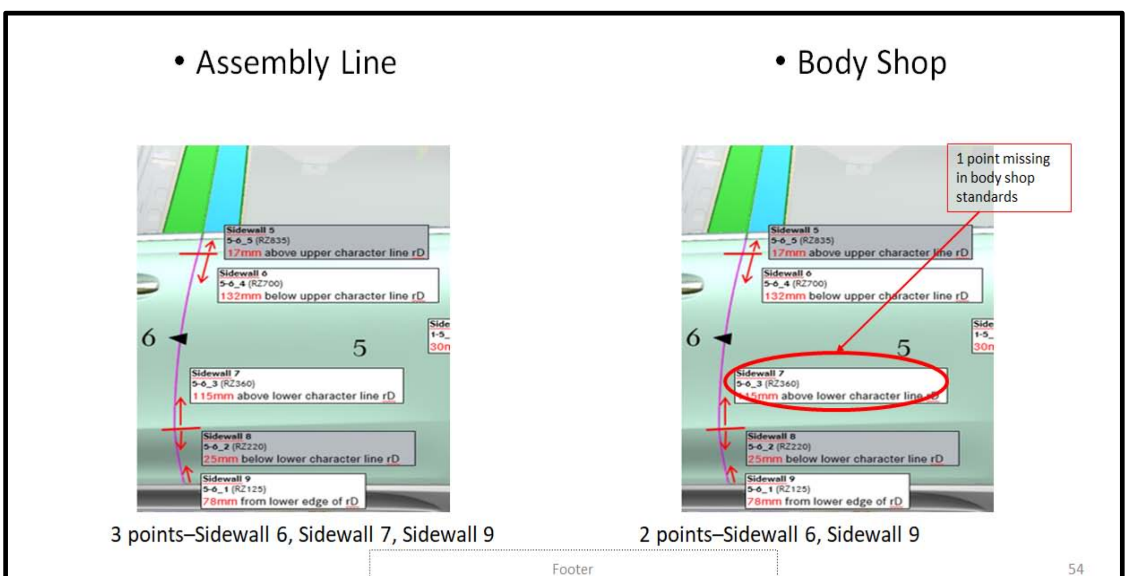

Figure 3: Door to door checkpoints

The checkpoint highlighted here, between 2 doors of the car is missing in list of specified Body shop checkpoints.

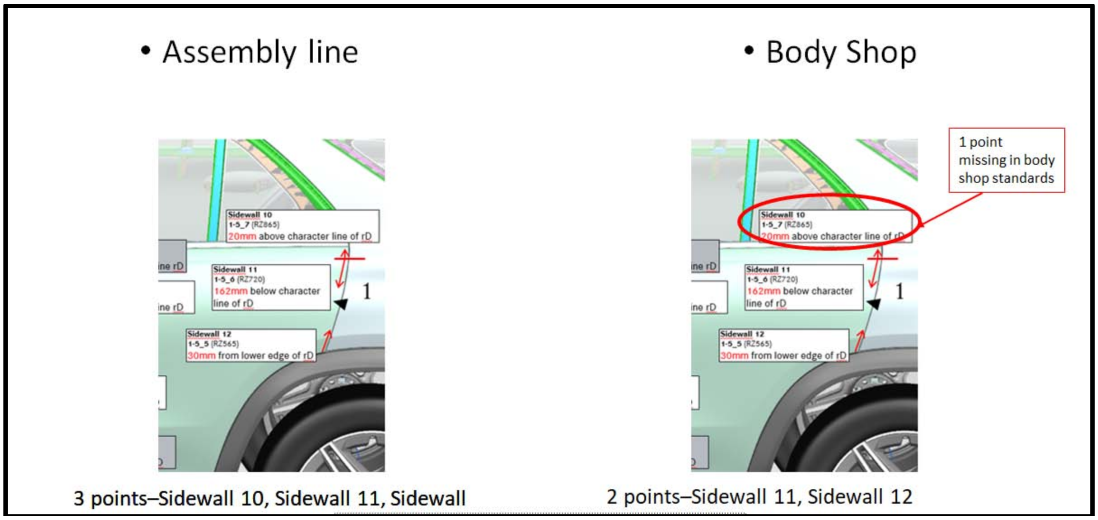

Figure 4: Rear Door to Sidewall checkpoints

The 'rear door to sidewall' of the car had three checkpoints at Assembly line quality-check workstation whereas Body shop quality-check workstation had two checkpoints.

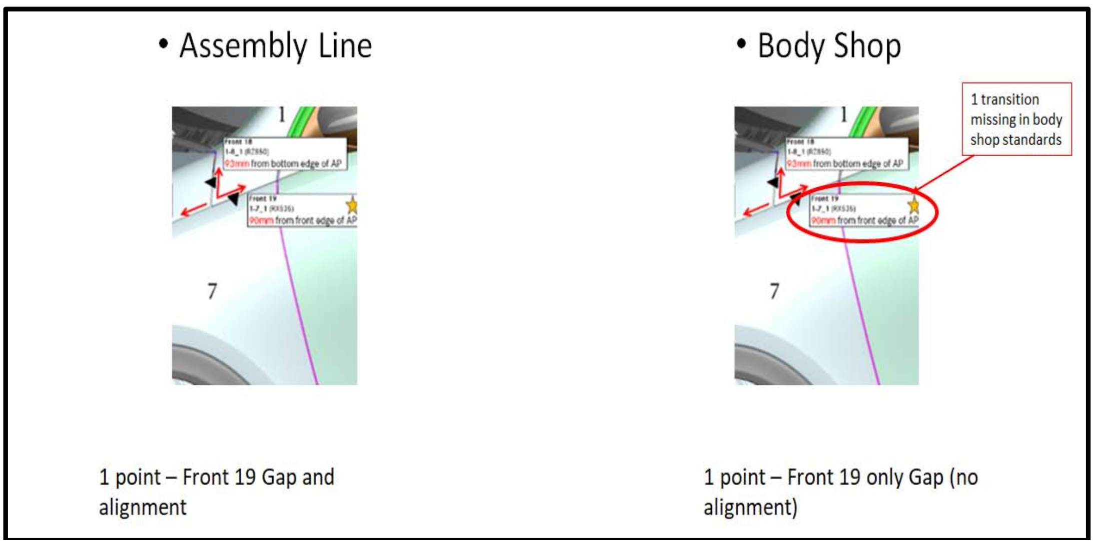

Figure 5: A-pillar to Fender checkpoint

Similarly, the highlighted checkpoint in fig. 5 was measured for gaps at the Body shop but the alignment was not measured whereas tolerance limits for alignment were specified at Assembly line.

b) Data Collection

- The data collection sheet was designed to accumulate data on a single sheet and 4 gap-checkpoints were decided to be monitored which affect every car and required urgent attention.
- These gap-checkpoints were present between 'fender and door', 'fender and bonnet', 'fender and A pillar' and 'rear door and sidewall'. 'Door to door' gaps were not monitored as cycle time was not increased drastically due to these gaps.
- These 4 checkpoints were measured at Body shop quality-check workstation to see if gaps were within tolerance.
- Then they were measured at Panorama workstation (first workstation of Assembly line) to observe the development of gaps when car comes from paint shop.
- Later, checkpoints were measured at workstation 18 of Assembly line before setting the gaps and alignment to see the variation caused by assembly process.
- After setting, data points at workstation 18 weremeasured to observe how setting these gaps affect other gaps.
- The data-sheet tracked gaps by assigned body numbers to different cars and a sample of the sheet is shown in fig. 6.

	Body No.	Major points LH															
		Body Shop				Panorama				ST.18 (BS)				ST.18(AS)			
		Front 15	Front 19	Sidewall 2	Sidewall 10	Front 15	Front 19	Sidewall 2	Sidewall 10	Front 15	Front 19	Sidewall 2	Sidewall 10	Front 15	Front 19	Sidewall 2	Sidewall 10
1	20389557	2.7	3.2	3.5	4.8	2.8	3.1	3.6	4.7	4.5	3.5	3.4	4.5	3.4	3.6	3.1	3.9
2	20388112	2.7	3.7	3.9	4.7	3	3.7	3.7	4.6	4.3	3.8	3.8	4.4	3.5	3.6	3.5	3.8
3	20388427	3.2	3.5	4	4.5	3.3	3.5	3.8	4.6	4.0	3.5	3.8	4.4	3.5	3.1	3.4	3.8
4	20388104	2.7	3.6	3.7	4.8	2.9	3.7	3.5	4.9	3.9	3.4	3.2	4.5	3.6	3.6	3.1	3.9

Figure 6: Sample Data Collection Sheet

c) *Plotting Graphs*

The data points at each stage for all four points were plotted on a line graph. The tolerance limits of Body Shop as well as Assembly Line were included in the graph. A sample of graphs for one of the checkpoints (Front door to Fender) considered is shown below.

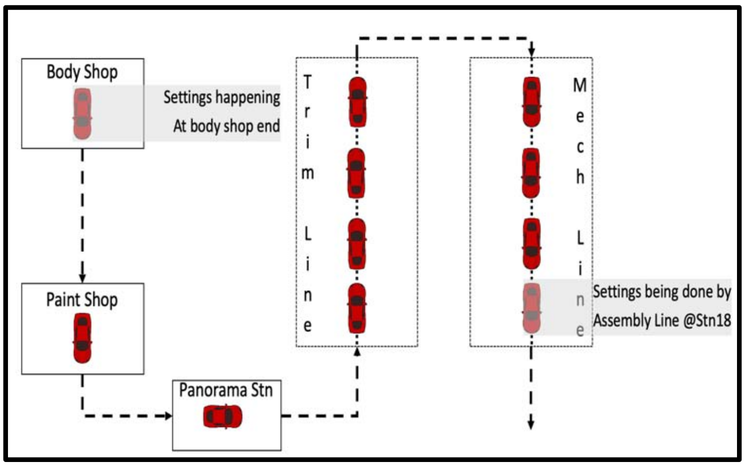

Figure 7: Flow of car through the Plant

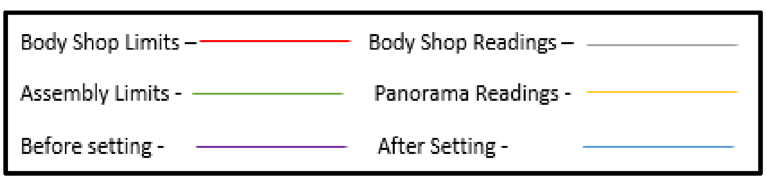

Figure 8: Legend

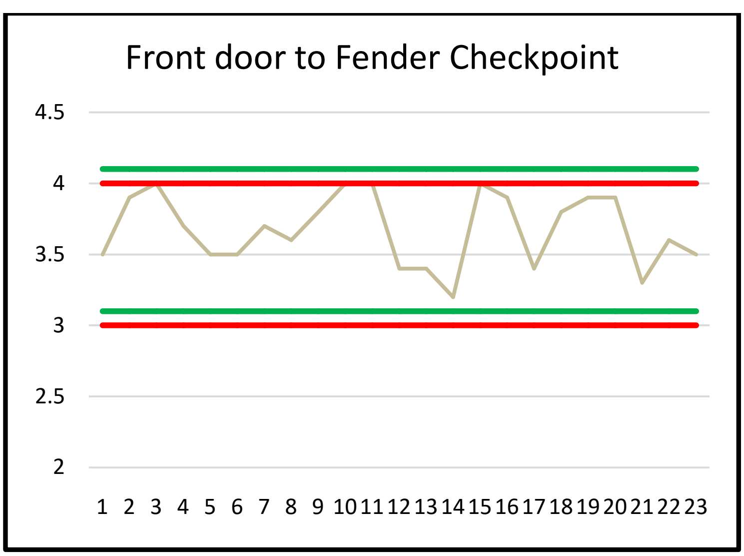

Figure 9: At Body shop quality-check workstation

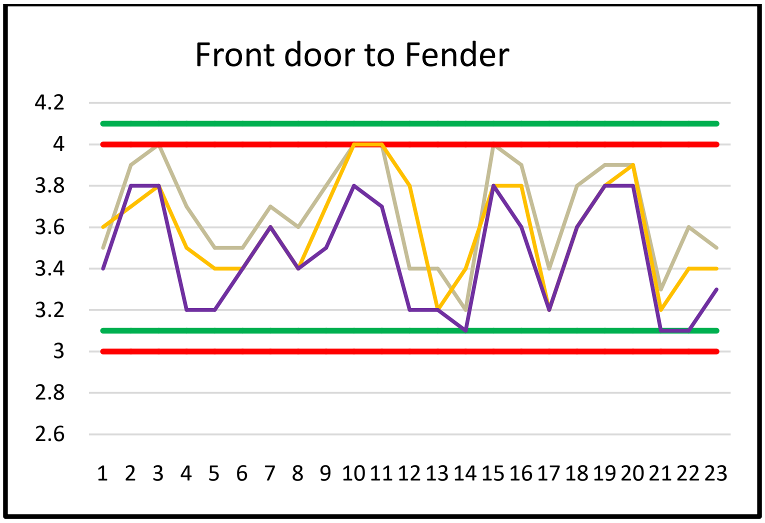

Figure 10: At Panorama workstation and workstation 18 before setting on Assembly line

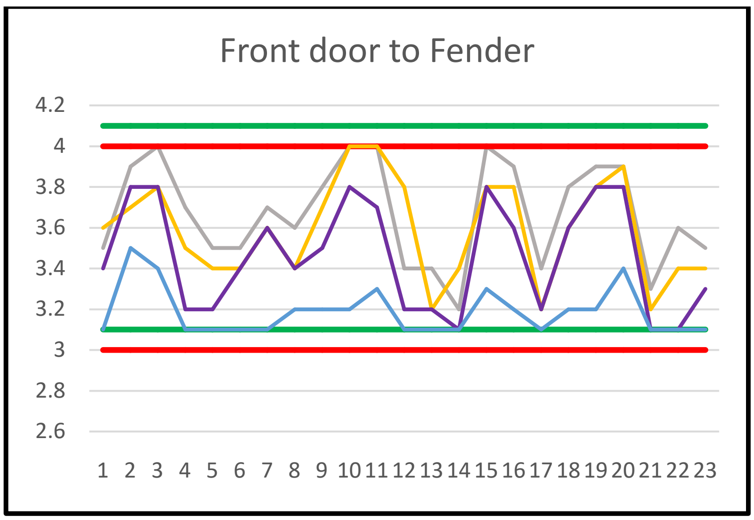

Figure 11: After setting at workstation 18 on Assembly line

Similarly, graphs for each checkpoint considered were determined at each of the four stages.

This process was implemented for gaps and alignment on both the left-hand side of the sample cars as well as the right-hand side. Final inferences were derived by analyzing trends of different gaps.

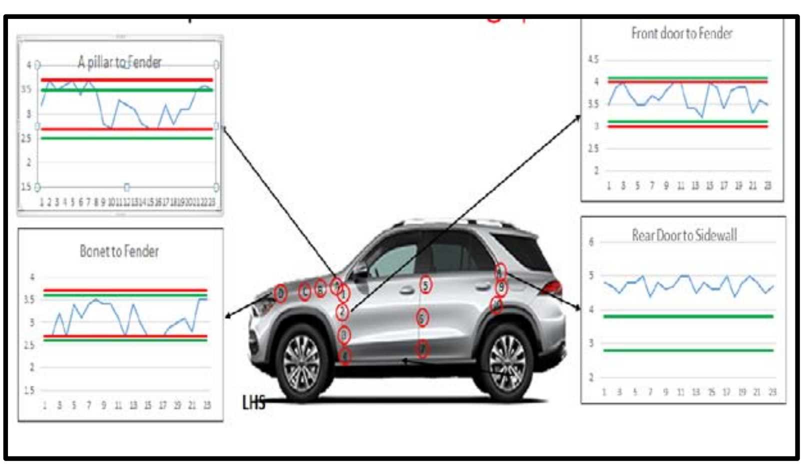

Figure 12: All four checkpoints at Body shop quality-check workstation

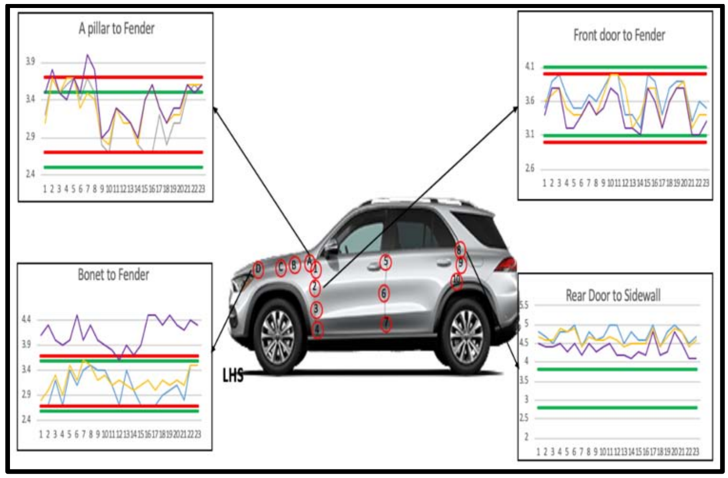

Figure 13: All four checkpoints at Panorama workstation and workstation 18 before setting on Assembly line

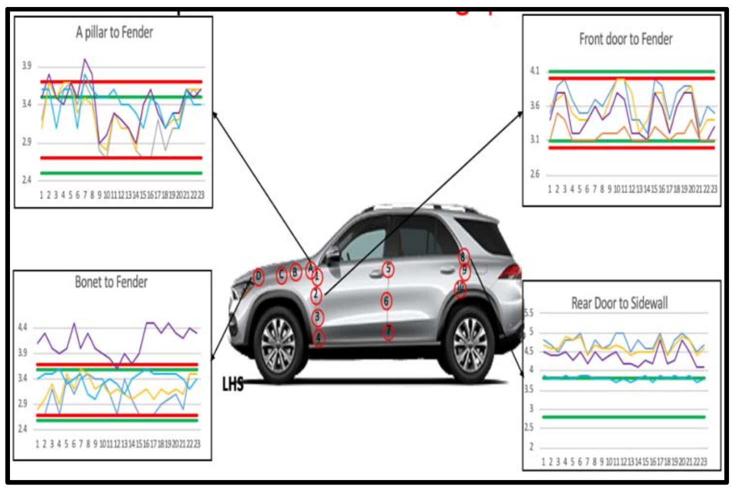

Figure 14: All four points after setting at workstation 18 on Assembly line

Inferences drawn from data points

- Body shop has no checkpoint for one of the points that was monitored (rear door to sidewall).
- Measurement of gaps Panorama workstation are consistently 0.1-0.2 mm lesser that gaps measured at Body shop quality-check workstation. This is due to the layer of paint that is applied when the car goes to Paint shop after Body shop.
- If measurements vary from panorama workstation to workstation 18 (without settings), we can assert there might be factors in the assembly process (workstation 1 through 18) which influence thesegaps. If the measurements do not vary from panorama workstation to workstation 18 (without settings), we can assert body shop's output quality might be influencing the gap setting issue as after quality check at Body shop, only variation is due to a layer of paint added at Paint shop.
- There is a change present in gaps and alignments measured at panorama station and station 18. Hence, assemblyprocess is responsible for some variation which means tolerance limits for Body shop and Assembly lineshould be different.
- Gap 1 (A pillar to Fender) – No substantial variation between Panorama and St. 18 Before Setting which suggests Body shop output quality is the reason for rejection of cars.
- Gap 2 (Bonnet to Fender) – Body Shop should keep the gap measurement in lower tolerance of Body shop specifications since before setting gap reading at workstation 18 in Assembly line is very high
- Gap 3 (Door to Fender) – Body Shop should keep Gap 3 in upper tolerance for it to be within specifications when car reaches Assembly line. But when Gap 3is kept within specifications at workstation 18 of Assembly line, another checkpoint between door and fender would not conform with its respective assembly line tolerance limits (>4.5mm) and hence, standards need to be revised.
- Gap 4 (Door to Rear Sidewall) – No major observation, checkpoint should be added for Body shop quality-check workstation which would result in greater frequency of conforming gaps.

IV. Results and Conclusion

Table 1: Recommendations

Checkpoint	Body Shop Standards	Recommendation	Remarks
A pillar to Fender	3.2+0.5 3.2-0.5	2.7-3.2mm	Within Body Shop Standards
Bonnet to Fender	3.2+0.5 3.2-0.5	2.7-3.2mm	Within Body Shop Standards
Door to Fender	3.5+0.5 3.5-0.5	3.1-3.6mm	Within Body Shop Standards
Rear Door to Sidewall	-	4.0-4.5mm	Checkpoint to be added

On performing root cause analysis and analyzing the trends of different measurements of gaps and alignment, recommendations of gap setting at Body shop are provided. Apart from that, standardization of the process, placing skilled operators for setting gaps and revising the standards was recommended.

Similar methodology can be implemented for other crucial gaps and alignments. Bonnet and front bumper gaps can be considered as cycle time is increased drastically if the process is not efficient and standardized. Further an electric measurement system could be used to minimize time required to take readings.

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- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.
22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.
23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- o Explain the value (significance) of the study.
- o Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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