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Applying Lean Principles to Road Transport for Improving Operational Efficiency and Sustainability

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Abstract- *This study examines the scope and impact of applying lean principles to road transport operation. Focus here is on the basic needs of the manufacturers who strive to reach their customers with value-added product - on time, with right quality, and at reasonable transportation cost. How lean principles and practices can benefit transporters, manufacturers and customers is the subject of this study. On the other hand, a review to support sustainable transport with application of lean is also conducted. While the author is tempted to accept that the lean principles have close relationship with sustainable transport, previous researcher suggests that transportation can turn out to be lean and green in specific cases only with planning and effort. Therefore this study attempts to find answer to his question; is the lean necessarily green in transportation perspective? Case study of an Indian manufacturing company helped in formulating the research problem. The company was required to supply continuously the important components of motor cycle of different models to an original equipment manufacturer (OEM) at a distance of about 988 kilometers in several containers every day. Inadequate research work on lean road transportation is evident when compared with the research carried out on lean application in other sectors including; supply chain management and logistics. This paper therefore attempts to complement and support the limited body of knowledge on lean road transportation, reviewing two lean-based principles and tool; Seven Transportation Extended Wastes (STEWs) and Transportation Value Stream Mapping (TVSM).*

Keyword: *Lean Road Transport, Sustainable Transport, Efficient Transportation*

I. INTRODUCTION

The road transport management system in today's competitive situation all around must provide safe, quick, economic, and convenient movement of goods. Transportation plays important role in promoting trade all over. Efficient mobility of men, machine, and material is a necessity for economic growth at individual as well as institutional level. People, industries, states, countries and governments equally depend on different modes of transport for fulfilling their missions. It facilitates production and consumption of goods taking place at different locations anywhere on the globe. Remarkable developments of science and technology have made things possible that appeared unimaginable before. But the past researchers and the present author argue that road transport management system needs drastic improvements. Surprisingly, moving an object from one location to another is not less challenging for industries today than it was before. O'Neill (2008) highlighted this fact with an interesting statement cited by [1]. According to him, it is possible to move an object from earth to moon in 8 hours and 35 minutes but it is impossible to move the same object from one industry to other within the same country in a truck, a car, a bus or even a plane without facing multiple transportation problems. His immediate concern was traffic congestion, transit issues and different regulations related to pollution, speed etc. Traditionally, transport problems used to be addressed through mathematical modeling, operations research, and simulation. These methods contributed towards improvement of transport operations since the mid-1990s. Criticism was on rise about their effectiveness to address real-life transportation problems. According to Ak and Erera (2007),[2] these approaches are kept at a level oversimplified by treating parameters such as demand, time, distance, and others, as deterministic, whereas real life situations are complex in nature. Since significant waste and unnecessary costs are normally present in most transportation networks, the application of lean thinking, alongside its principles and tools, has emerged as an opportunity to complement the traditional improvement methods. This may contribute towards overcoming some of their limitations while addressing the improvement of road transportation. In the last a few years focus of transport operators and researchers found shifted to application of lean principles and tools to road transport operations for achieving all-round improvements as evident from [3].

The author carried out study to understand transportation from different perspectives as an exploratory research work. The study includes sustainable transport, lean transportation, and case study. Thereafter special focus was put on the problems faced by Indian industries on account of road transportation issues. Efforts have been made to answer the questions from the experience and learning of the world's successful companies in the same field. Application of lean transportation principles provided solution to transportation problems on one hand and paved way for developing sustainable transport on the other hand. Lean solutions to transportation problems have been examined in detail in methodology section. In this context Toyota concluded long ago, no process is perfect for long and issues do arise. For example, buyers are continuously looking for special offers from transporters, and transporters are tempted to make special offers even if such offers can upset the logistic systems by introducing sudden spikes in demand or supply. However, practitioners of lean solution advocate that the most part of the system works well, and it certainly works far better than the traditional system it replaced.[4]

Research questions that were framed include: (i) Can lean principles and practices be applied to road transport operation to meet customer expectations efficiently? (ii) Are the wastes generated in transportation connected and convertible in any other form or unit with the environmental green wastes?(iii) Are the lean transportation and sustainable transport complementary to each other or are they in conflict? The questions were approached through different angles to find answer using; literature review, case study, statistical operation research, and interaction with the professionals engaged in the field. Research problems are related to transportation issues. Some of the critical problems include; reliability and equipment availability to provide quality service, scheduling options, timely deliveries, track to provide real-time data, visibility across the transportation network, lead time variability control for reduction, timing of pick-ups & arrival of materials, time waste in transit and other process, flow of right information at the right time, availability plus retention of competent staff, and slow development in transportation services. Vision of flow of right information and goods at right time from the trained competent staff and drivers can be realized as claimed by lean practicing professionals, where transporters, suppliers, and customers work together as collaborators and not as strangers. This paper in other section examines development of sustainable transport and impact of applying lean principles to achieve specified goals of sustainable transport. Further, targets and indicators have been reviewed with reference to recommendation made by United Nation and communicated through their official publication. The publication suggests in nutshell that sustainable transport is: safe, affordable, accessible, efficient, flexible but strong, and environmental friendly minimizing carbon emissions. Sustainable transport is also known as Green Transport and it is any form of transport that does not use scarce natural resources. Instead, it uses renewable energy like solar power or hydrogen rather than fossil fuel [5].

As regards limitation in this research work, author likes to state that it does not include all lean management principles and practices. On the other hand it does not examine application of lean principles to all modes of transportation. Some secondary data from industries were selected and Judgment sampling was used due to availability of limited time. However, precautions were taken as required while using such non-probability sampling method ensuring validity and reliability. Significance of this research work lies in selecting the real-time problem faced by industries, customers, and transporters with a view to finding scientific solution for improving operational efficiency while developing sustainable transport. The study was carried out in industrial environment involving connected professionals and therefore is expected to benefit participant industries.

II. LITERATURE REVEW

After having found research problems and questions, the author sets out to review the relevant literature. Purpose is to provide background of the topic under study. While this section examines result of previous studies, investigates also the recent developments in the selected field. The synthetic data and investigation indicate that transportation plays important role in supporting trade and communication. Efficient transportation adds value to the moving products. Therefore transportation needs to implement advance techniques and lean management principles to improve the delivery speed, service quality, operation costs, optimization of facilities and energy saving. Review of current challenging issues faced by transportation and their solution through application of acclaimed lean principles for improving operational efficiency and sustainability have been examined in subsequent section of this paper.

2.1 Lean transportation

Previous researchers considered waste elimination as a fundamental aspect in Lean literature. A process can be separated into value adding and non-value adding steps, also called waste, according to market's needs. Toyota Production System was the first to contribute in the waste identification process. At Toyota, Ohno defined seven major types of waste in manufacturing and business processes [6]. These include overproduction, waiting, unnecessary transport, incorrect processing, excess inventory, unnecessary movement and defects. References [7] show that a great deal of waste remains yet to be identified and eliminated in the administrative processes that support shop floor operations. In order to facilitate it, they adapt the seven wastes previously described for manufacturing operations to administrative processes, adding a new waste of underutilized people. As the focus of the value stream includes the complete value adding (and non-value adding) process, from conception of customer requirements to the consumer's receipt of product, there is a clear need to extend this internal waste removal to the complete supply chain.

The seven wastes previously mentioned required an adaptation to the supply chain environment. Reference [8] developed a process mapping tool called Value Stream Map (VSM) for the extended enterprise, looking to identify waste between facilities and installations in a supply chain.

2.2 The basic principles and practices

The basic principles and practices of lean were reviewed in detail to examine how these can be applied to transportation for better efficiency. In 1980s the term lean production was first referred to Toyota Production System (TPS). The system was explained through a set of five principles and was named as 'Lean' by a research team of MIT (Massachusetts Institute of Technology) under the leadership of Prof. James P. Womack and Prof Daniel T. Jones. It was labeled as 'lean' because it uses less of everything compared to mass production – half of the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it requires keeping far less than half the inventory, results in fewer defects, and produces a greater

and ever growing variety of products. The thought process of lean was thoroughly described in the books; The Machine That Changed the World (1990) by Womack and team [8]. The theory of lean was expanded in his book, 'Lean Thinking' (1996). This book identifies the five main principles of lean: (i) define customer value (ii) define the value stream (iii) make it flow (iv) 'pull' by the customer and (v) strive for excellence.[9] His other book, 'Lean Solutions'(2005) recommends how companies and customers can create value and wealth together.[10] Jeffery Liker in the book, 'The Toyota Way' recommends important tips to transform any business to a lean enterprise. Lean literally means the ability to achieve more with fewer resources by eliminating waste. As pleaded by several book authors including Akhilesh (2010), lean is now not only limited to manufacturing, but being successfully and effectively applied in all kind of non-manufacturing, office and service processes including healthcare, education, construction, government, supply chain, public administration, software, product development etc. Improvement tools, techniques, methods, and systems that are used for lean implementation include: value stream mapping, kaizen, five S, just-in-time, jidoka, heijunka, one piece flow, mistake proofing, visual management, single minute exchange of die, standardized work, Kanban, total productive maintenance etc.[11]

2.3 Lean answer to transportation problem

Searching of lean answer to road transport problem is the immediate concern of the author. Attempt has been made to find how lean principles and practices can be applied to transportation services to meet expectations of customers efficiently. Transportation companies are facing challenging situation today on many fronts due to increased customer requirements related to flexibility, reliability, uncertainties, risks, and competition. Therefore, new transportation management solutions are needed for survival. Need of the hour is to cut transportation costs despite inflation at one hand and meet enhanced service quality expectation, profitability for stakeholders, and motivation for employees on the other hand. Opinions and results are found encouraging. Despite criticism lean was adopted for improving performance by transportation industries. It has been also pleaded that lean not only can result in operational, administrative and strategic improvements but it can also act as a survival strategy in recession period. A lean model for transportation propagated by Samira (2002)[1] has been critically examined to search solution. Three relevant lean tools are found instrumental in enhancing efficiency of transportation services. They are: JIT (Jus-In-Time), Jidoka (automation), and Heijunka (production or load leveling). Concepts of these tools are first examined and then their applications to transportation also are analyzed.

2.3.1 Waste elimination in transport operations

Two main approaches based on waste elimination have been suggested for improving transport operations: The first scheme was initially proposed by [12]. This contribution recommends a new measure called Overall Vehicle Effectiveness, OVE, to be used for improving the efficiency of truck transportation. This is an extended version of the Overall Equipment Effectiveness indicator employed in lean manufacturing to improve single equipment efficiency. The second, a modified version of the OVE measure is suggested by [3]. This is called Total Operational Vehicle Effectiveness, TOVE and considers total calendar time instead of loading time and includes additional waste concepts as shown below:

OVE = (Availability) x (Performance) x (Quality), ie.; OVE is affected by 5 big losses:

Where; **Availability** accounts for 2 big losses at Stationary Condition: (i) Driver breaks and (ii) Excess load time.

Performance is based on capacity losses: (iii) Fill loss, and (iv) Speed loss.

Quality represents service delays and termed as; (v) Quality loss.

TOVE = (Administrative Availability) x (Operating Availability) x (Performance) x (Quality)

Where: many important wastes are considered for calculation such as; Non scheduled time, Scheduled maintenance, Not in Transit (NIT) activities, Excess load / Unload time, Driver breaks, Unscheduled maintenance, Waiting & Excess, service time, Fill loss, Speed loss, Excess distance, % Demand not met, % Product defects.

The concept was propagated by [3] advocating the vehicle administrative availability as important because it has a significant impact on the overall vehicle utilization and efficiency. It is mainly the result of administrative policies and strategies related to capacity or maintenance decisions.

The Lean performance measures for road transportation as adapted by [12] was actually extension of the Overall Equipment Effectiveness (OEE) metric, used by the lean Total Productive Maintenance (TPM). This approach to measure equipment effectiveness, developed as new metric called Overall Vehicle Effectiveness (OVE). This metric was used for measuring and improving the performance of truck transportation. Subsequently, The result of this study was that five out of the seven classical waste types can be applied in this waste framework, but two do not fit, namely waste of excess inventory and conveyance. Instead, two new waste types are included: resource utilization and uncovered assignments

Descriptions of Seven Transportation Extended Wastes (STEWs) for transport operations are as below:

(1) Overproduction - Producing reports that no one reads or needs, making extra copies, e-mailing/ faxing the same document/ information multiple times, entering repetitive information on multiple documents and ineffective meetings.

(2) Waiting - Employees having to stand around waiting for the next process step, such as loading and unloading, or just having no work because of lack of orders, processing delays, equipment downtime and capacity bottlenecks.

(3) Incorrect processing - Consuming more resources for moving the goods than necessary due to inefficient routing or driving.

(4) Unnecessary movements - Any wasted motion employees have to perform during the course of their work, such as looking for information, reaching for, or stacking goods, equipment, papers, etc. Also, walking and extra movement created by sequencing errors is waste. This was found to be synonymous with conveyance.

(5) Defects.-Waste caused by repairs, redelivery, scrapping, etc., due to damages on the transported goods or the equipment.

(6) Resource utilization **(new) -** Waste due to excessive equipment and bad resource planning.

(7) Uncovered assignments **(new) -** Carrying out unprofitable transport work due to lack of information or planning

These types of waste are related to the improvement of the Operational Vehicle Effectiveness (OVE) and Total Operational Vehicle Effectiveness (TOVE). Therefore, a systematic method for improving road transport operations based on the elimination of the *Seven Transportation Extended Wastes* (STEW) has also been suggested. Possibility of finding inter-relationships between the efficiency waste schemes with the STEWs and also exploring the possibility of using them for building more effective improvement procedures may be the future requirement. This paper is intended to review such study and find a potential scheme that considers the identification and elimination of both type of wastes. According to Sternberg's *et al*. (2013)[13] STEWs were developed and validated through multiple case studies and they conducted in-depth interviews with carrier operators, carrier technology providers and carrier service buyers. Hence, these wastes identified by him were used as the basis to improve the road transport operations of the Mexican organization.

For improvement of road transport operations, [3] also developed a methodology to reduce transport waste by integrating the Just-in-Time approach of milk runs with the traditional operations research approach of developing algorithms to optimize vehicle routing. Additionally, he adapted the lean's Value Stream Mapping (VSM) tool to support efficiency improvement programs in transport operations. He called this adapted tool Transportation Value Stream Mapping (TVSM). Subsequently he also developed a scheme for increasing transportation efficiency that was validated with its application in a Mexican firm.
Other approaches for waste reduction and efficiency increase in road transport operations, other than Lean, for the reduction of waste and improvement of efficiency also are in use. They are not based on lean practices or lean tools. Sanchez Rodriguez *et al.* (2014)[14] suggest that avoiding extra travel in road freight operations is very important as these operations result in low-profit margins. For this reason, they proposed a measure, called "Extra Distance", which intends to reduce the additional operational costs associated with transport disruptions. Similarly, they proposed a model to improve the efficiency of freight transport through a better management of supply chains' uncertainty.

2.3.2 Just in time (JIT) transportation
JIT transportation aims at regulating the right goods needed by customer. Goods reach the site at the time when they are needed and only in the required quantities. This system is for reducing the inventory at minimum possible level. Such effort reduces storage space, inventory carrying cost, man-hours and material handling time. Although JIT started in the automobile industry, today it is applied successfully in transportation process. Application of JIT in transportation as a newly adopted system provided more frequent movement of goods, in smaller quantities and in a tighter schedule. Initially transportation carriers were worried and concerned about optimum use of their capacity while applying JIT system. The dilemma was solved through collaborative approach of all players in the whole supply chain including shippers and carriers assessing what is better for whom and how to optimize the whole system to have more win-win situations[1]. In non- JIT transportation system, pushing full loaded trucks to market will minimize unit transportation cost, but it will increase the risk of non-answered demand if goods are not accommodated due to the occasional demand fluctuation. Such system will also result in late deliveries, dissatisfied customers, and waste generation as suggested by Womack & Jones (2003).[4] On the other side, JIT transportation system provides continuous flow, desired lead time and advantage of pull system to eliminate waste.

2.3.3 Jidoka in Transportation
Jidoka is actually automation system with human touch in transportation and its concept was examined. The aim of Jidoka is to prevent the process producing defective goods by building quality into the product. It implies that process has to be interrupted as soon as abnormality appears. And it is the employee who has the responsibility of stopping and correcting the process. It is also important not to delay any corrective measure and ensure that all corrections eliminate

the root cause of the problem. Jidoka is important because it promotes a culture of continuous improvement without which it is not possible to sustain lean results and advantages. The best achievement is to bring Jidoka and the resulting culture of continuous improvement into employees' daily work and activities. Application of Jidoka in transportation ensures prevention of all quality problems in the transit. It is done by correcting issues like equipment malfunctioning, delay due to any reason or any other abnormality. In any such case, the driver takes corrective action and informs the supplier about the issues. Under Jidoka system a solution would be developed right there on the spot[1]. It is therefore important that the driver is well trained to perfectly verify; ordered goods, quantity, the packaging, the labeling and any other special requirements expected. If something is found missing or not conforming with the standards, the process is stopped immediately by the driver and the supplier is informed about the missing thing at the earliest stage possible. Therefore implementing Jidoka to transportation will require drivers and all employees to be involved in a continuous improvement process. This will ensure quality at the source and eliminate wastes from transportation process.

2.4 Sustainable transport

2.4.1 Environmental management integration with lean thinking

Exploratory review has been carried out to integrate environmental performance in transport operation with the lean road transport. Lean management implementation through identification and reduction of wastes, is one of the good practices and is used in value stream mapping. Wastes negatively affect efficiency of any function, be it manufacturing, transportation or supply chain management. When environmental impact of different categories of waste are quantified in common units like; pounds CO_2 emission per kilowatt-hour, it becomes easy to measure, compare and bring continuous reduction. B. Wills (2009)[15] thoroughly explained each of lean waste converted in his green waste through a conversion table illustrated at Table 1[16]. [source; Kristen Carbon Footprint]. This way, greenhouse gas emissions are measured in units of carbon dioxide equivalent. Greenhouse gases are compared in terms of their GWP (Global Warming Potential). Conversion factor takes reference of carbon dioxide gas; 1 kilogram of CO_2 has a GWP of 1 while, the same amount of CH4 has a GWP of 21[US Env. P.A2006]. Transportation fuel emission conversion factors are now available in pounds per ton-mile as a convenient unit. An extract of this conversion table is illustrated at Table 2 [17] [source: Kumar Venkat]. Therefore answer to the research question (ii) is available and wastes generated in transportation found connected and convertible in a standard unit with the environmental green wastes.

Table 1. Energy emissions Table. Conversion factors.

Fuel type	Lb CO2E per kWh
Gasoline	0.53
Diesel	0.55
Mix fuel	0.44
Natural gas	0.40

2. Characteristics of road transport

Transport Mode	Maximum Load[1] (Kg.)	Fuel Type	Specific total CO2 E (g/tonKm)
Heavy Duty Truck	17300	Diesel	62
Midsize Truck	6000	Diesel	122
Light Truck	700	Gasoline	459

Further review was conducted to find if the lean transportation and sustainable transport are complementary to each other or are they in conflict. An analysis carried out by Kumar Venkat [17] on generic supply chain, manufacturing supply chain, food supply, and transportation- all show clearly that lean transportation do not necessarily reduce carbon dioxide emissions, particularly when travel distance is long. When cold storage is not required for a particular product, emission depends mainly on the transportation mode. Larger deliveries at less frequent intervals along the supply chain generally lead to the lowest emission. When cold storage is required along the supply chain, it is found advantageous to keep inventory levels low. But this increases transportation emissions due to more frequent deliveries. Consequently, an optimal order size may balance inventory level and delivery frequency [17].

2.4.2 Development of sustainable transport

The principle of sustainability is not just an environmental one, but is about simultaneously delivering social and economic benefits. Lean and sustainability are quite similar as they require more leadership than financial investment but they follow different criteria. Both can be treated as journey rather than specific project. Contributing literature on sustainable transport by the high-level advisory group of United Nation [5] has advanced a definition, "sustainable transport is the provision of service and infrastructure for the mobility of people and goods – advancing economic and social development to benefit today's and future generation – in a manner that is safe, affordable, accessible, efficient, and resilient while minimizing carbon and other emissions and environmental impacts". The literature further argues that sustainable transport could only be achieved in close coordination with all stake holders like; transport industry, research institute, local & central government and area based public organizations. Sustainable transport, among other things, puts efforts to fight climate change, reduce air pollution and improve road safety. Sustainable transport works effectively on 5Ps, 5Is, and 5Cs principle. Respectively these are; people - planet- prosperity-peace-partnership, infrastructure-innovation- integration-intelligence- investment, and client- centers- corridors-congestion-

complementary. Enabling is added to the framework and therefore innovative technologies are integrated into sustainable transport drive to achieve desired results. Autonomous vehicles are example of enabled technology. Development of alternate fuels like; bio-fuel for aviation, compressed natural gas (CNG) and liquefied natural gas (LPG) for heavy truck will support sustainable transport goal.

III. METHODOLOGY AND METHODS ADOPTED

Research methodology is a way to systematically solve the research problem. Methodology helps in selecting appropriate method and technology for solving specific problem. In the present study mixed method of qualitative and quantitative method has been used. The review of current literature has provided input to the qualitative aspect of the study on road transport on one hand and lean on the other hand. As regards quantitative method, analysis of data collected from the entire process of transportation provided clear opportunity to eliminate waste which was the major source of inefficiency. Effort was made to link all the eight lean wastes to that of transportation waste. Late delivery and damaged goods were identified as defect waste. Wrong destination caused unnecessary transportation, changeover and waiting at different stages resulted in time and speed loss affecting lead time and quality of goods because of excess material handling. Discussions and process of eliminating the identified waste in transportation is addressed in the case-study.

Other concept and methodology deployed at a Mexican firm provided one point lesson. The method was found equally applicable to any country for improving efficiency of road transport operations. According to [3], the TVSM analysis consists of two main facets; one that included secondary activities carried out by warehouse operators. This advice was taken into consideration when proposing the pre and post transport and serving clients, known as "Not-In-Transit (NIT)" activities, and the other that contemplated activities related to the actual physical distribution of the product, known as "In-Transit (IT)" activities. As a consequence, 35% of transport capacity was under-utilized and there was a 19% of distance per route travelled in excess. It was found that 40% of the total time of closing routes was classified as waste due to problem. The author further suggested that vehicle drivers should focus on performing IT activities only, whereas the execution of NIT activities should be carried out as improvement initiatives derived from the value stream and STEWs analyses of the transport operations studies.

3.1 Case study

In order to illustrate the method proposed in this paper, a case study was performed using example of Indian Auto Industries. The company was required to supply important components of motor cycle of different models to an original equipment manufacturer (OEM) at a distance of about 988 kilometers in several containers every day. The transport problem caused repeated serious customer complaints for; (a) damaged parts (b) late deliveries. At this critical stage experts from OEM customer intervened under vendor development drive in line with lean practices they followed. The author of this thesis was actively associated as a team member. Following steps were taken for solving the problem:

(i) A cross-functional team was formed with members drawn from; transporter, quality department, and dispatch department. The members were closely associated with the processes involved.

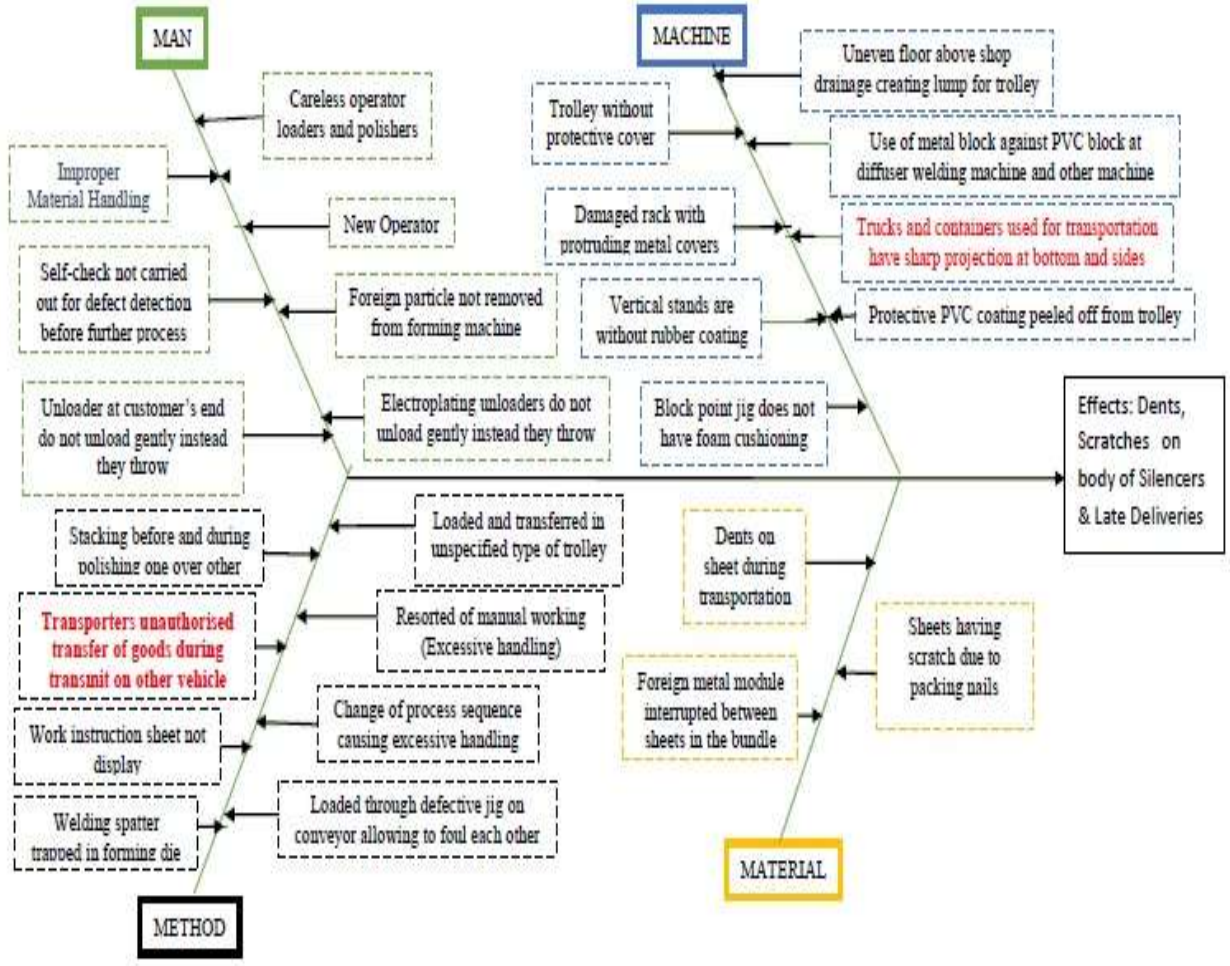
(ii) Company's cost of quality was analyzed based on 90 days data. Distribution revealed; prevention cost 5%, appraisal cost 30%, and failure cost 65% of total quality related cost. Comparing with the bench mark company, the target was fixed to reverse the proportion reducing failure cost drastically. This work was done to determine the impact of the customer complaint on cost to the company, in addition to loss of good-will.

(iii) Next step taken by the team was to analyze failure cost in depth. The analysis revealed proportion of failure cost on all the three products A, B, and C separately in % of sales value of the respective product as; 0.8%, 0.4%, 0.2% respectively. The analysis indicated that product 'A', muffler (silencer) required greater attention for bringing down failure cost that would automatically reduce total quality cost of the company.

(iv) The fourth step was taken to find root cause or causes for the failure of product 'A'. Fig.1 below shows the root cause analysis method propagated by Ishikawa[18] and that was carried out using 'Fish bone diagram'

under four heads: man, machine (equipment), material, and method. Analysis of 26 minor and major causes got reduced to two root causes only. Fig 1.below shows two identified root causes, one each under headings machine and method. First cause illustrates that 'trucks and containers used for transportation had sharp projections at bottom and sides' and the effect produced was damaged mufflers (silencers) bearing dents and scratches on the finished electroplated body. Second 'cause' in Fig.1.reveals that practice of 'transporter's unauthorized transfer of goods during transit on other vehicle' resulted in late deliveries.

Fig.1. Root Cause and Effect Analysis Diagram (Drawn by the author Suresh Sharma)



(v) Therefore, root cause of customer complaint (a) and (b) got established using the Ishikawa diagram also known as fishbone diagram or root cause and effect analysis diagram. Dents and scratches were found taking place inside the container on the product at the bottom most floors due to several protruding thread bolt heads. The other abnormality during transportation that aggravated the problem was - unplanned changeover of carrier and waiting at different stages. This resulted in time and speed loss affecting lead time and quality of goods because of excess material handling.

The appropriate corrective and preventive majors were taken. The problem was brought under control gradually and satisfactorily.

3.2 Analytical lessons learning

Historical basic research of the past has established that 'prevention is better than cure'. Making use of this outcome the procedure already documented for packaging & dispatch function must be religiously implemented. Routine container inspection before loading would have prevented customer complaints and losses. However, no process is perfect for long, and problems do arise. But, there should be no delay in applying well structured problem solving qualitative techniques to identify the root cause of problem for immediate solution without waiting for external interventions advised by Ishikawa [18]. He also advocated need for 'dogged use of process analysis and quality analysis that has brought about improvement in technology'. Concept of in-transit (IT) and not-in-transit activities need to be clearly understood, owned, and implemented by the concerned person for strict compliance.

IV. CONCLUSIONS

Objective of this research has been to examine and find applicability of lean principles to road transport operations for improving efficiency. The focus was on real-time problems faced by manufacturers to deliver their products to customers safely and on time. This aspect was designed to provide significance value of the selected research work**.** The author carried out study to address transportation from different perspectives. Discussions are documented in literature review section. Efforts have been made to answer lean and green transportation related three research questions

pertaining to; applicability of lean principles, linking of lean waste to environmental green wastes, and relationship between lean with sustainability. It was established through investigation that transportation and logistics systems have interdependent relationships. The research work took an upward step in reviewing the need for developing sustainability in transportation management by taking care of environment, society, and economy in an integrated way. Finally through the case study, two of the 'wastes' in terms of damaged product and late deliveries were identified using quality tools like cost of quality, and Ishikawa diagram method of root cause and effect analysis.

Inadequate discussion on 'pull' principle of lean in this paper prompts the author to add as one of the most important learning of Toyota. Womack [19] advanced an argument advocating its importance. Company like Toyota 'pulls' needed materials from its suppliers, frequently and in exact amount needed to ensure smooth flow, using periodic pickup and drop-off provision. If industrial consumers depend totally on providers to shift goods at the suppliers' discretion, shortages are bound to result. This requires enlightenment of all the players in the supply chain to achieve smooth flow. Transportation professionals may face practical problems while implementing pull strategy but survival and continuous growth are the motivating awards. The best way to handle the challenge of pull strategy, as recommended by James P. Womack, is to coordinate with real customer to know exact requirement and to work backwards to supply as desired [19]. This suggestion was implemented by OEM by providing a small warehouse as pickup point where small inventory maintained.

Two new approaches for waste elimination from road transport operations OVE and TOVE [20] have been studied and discussed in detail. Also TVSM that concentrates on identifying waste related to transport efficiency has been preliminarily discussed for further exploration and integration with allied concepts relevant to lean road transport operations. Future work on these relatively new concepts will be interesting and useful in improving road transport operations.

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