

Manufacturing Lead Time Reduction towards Zero-Defect Manufacturing

Tawana Jaff and Atanas Ivanov

Brunel University, Uxbridge, Middlesex, UB8 3PH, UK
School of Engineering and Design, Advanced Manufacturing and Enterprise
Engineering
atanas.ivanov@Brunel.ac.uk

Abstract Companies seek to reduce manufacturing lead-time in order to reduce the cost of the production; short lead-times are a major source of potential competitive advantage and can help achieve zero-defect manufacturing (ZDM). The quality of a product is dependent on both facilities (or equipment) and the manufacturing process. Any unexpected obstacle or glitch can create longer lead-time, which will prevent the product from promptly reaching the customer. A focus on reducing lead-time, therefore, will ensure an elimination of error, and work towards a zero-defect manufacturing system, which is necessary to increase the reliability and safety of manufacturing set ups and systems. This paper proposes a study on reducing manufacturing lead-time (MLT) in factories in the Kurdistan region of Iraq, where lead-time has become a major issue in the manufacturing industry. The aim is to provide guidance to industry practitioners/technicians on how to reduce MLT. The paper will present a conceptual framework of the causes of excessive lead-time and also describe the relationship between setup time, operation time, and non-operation time in order to find potential methodologies that can reduce lead-time in the manufacturing process. It will also further identify simple strategies for reducing lead-time that can help towards achieving ZDM.

Keywords: lead-time reduction, throughput time reduction, manufacturing management, zero-defect manufacturing

1. Introduction

The manufacturing practices and processes have faced increasing pressure from global competition and the need for a shorter lead-time is now more pressing than ever. Lead-time has several definitions. It may be regarded as the time between when the customer makes an order and when the customer receives the finished product. However, according to [2, 3], it is the time that elapses between the placement of an order and receipt of that order into the inventory. In purchasing systems, the lead-time is the time between the recognition of the need for an order and its receipt, whereas in production systems, lead-time is the ordering, waiting, moving, queuing, setup and run times for each component, according to [1]. Therefore focusing on MLT is important for further to work on, because MLT is the sum of setup time, processing time, and non-operation time according to [9].

Nowadays, most modern manufacturing companies are driven by rapid technological advancements. High-value manufacturing processes are increasingly moving towards flexible, intelligent production systems, and shorter manufacturing lead times. Although MLT reduction can be a daunting task due to the many factors that influence it and their complex relationships [7], however there are basic principles that, if applied correctly, can be used to reduce MLT and work towards ZDM. This paper proposes a study on the reduction lead-time in the manufacturing industry and provides guidance to industry practitioners on how to reduce manufacturing throughput time towards achieving ZDM. The factors that can reduce the manufacturing throughput time are not always clearly identified and understood [4]. A little specific research has been conducted on the formulation of MLT, which could be used as guidance for achieving a shorter MLT. This research paper identifies certain key factors that should be considered in MLT reduction studies. The research work will focus directly on manufacturing lead-time and identify simple strategies for reducing it. The first step is the surveying procedure, which is the best strategy for reducing defects in the manufacturing process. The survey questionnaire conducted in Northern Iraq in order to evaluate and assess the performance of manufacturing systems in that region and to identify ways in which to approach ZDM and through lead-time reduction. The future work are case studies which will be designed and developed from two published case studies by Johnson (2003) which focus on lead-time reduction efforts in four plants [7]. This dual theoretical and technical approach (analysis and case study) to manufacturing management will enable recommendations to be made to reduce lead time in order to work towards ZDM, see (Figure 1).

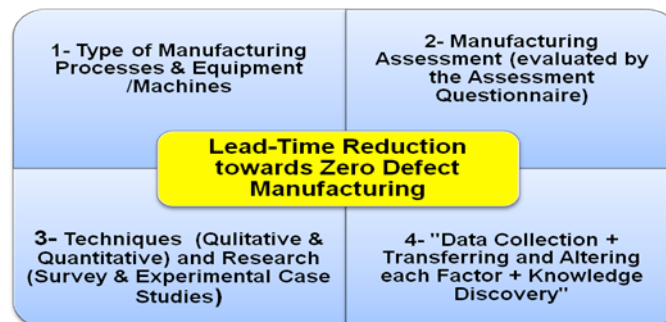


Figure 1: Research Strategies for Lead-time Reduction towards Zero Defect Manufacturing

2. Lead time- Literature Review

For the purpose of this research, an exhaustive search has been made of the literature related to lead-time reduction. Firms cannot ignore the demands for improved customer service, greater diversity in the scope of the product line better quality, quicker response and a much shortened time-to market for newly introduced product introduction. These therefore, are the key to analyzing how lead-time can be reduced. Lead-time reduction is comprised of various components (process time, moving, waiting/queue, setup, lot size, and rework time) most of them which should be treated as controllable variables in our study, It is necessary to use game theory to analyze the lead-time reduction because many writers have discussed the importance of lead times, but the most important thing that since no organization can excel in all these factors simultaneously. If a firm competes on quality and lead-time, then it should be judged in terms of its ability to deliver quality products in a timely manner. For instance, in early papers, assumed that lead-time is random and analyzed the problem of investing in reducing lead-time randomness. See [10]. For similar models see [11, 12], while the new research shows the relation between customer order lead-time-based decisions & potentially the source of competitive advantage, stated that “(the impact of customer order Lead Time-based conclusions on the firm's ability to earn money)”; according to [13, 14]. While lead-time reduction strategies are responses to numerous logistical chain problems, such as procurement, manufacturing, and distribution problems. [26]. Many of the quantitative models focus on the effects of lead- time reduction on operational decisions but they do not know if the demands some times are uncertainly. Lead-time has influenced by these logistical key figures such as (work in Process) WIP, utilization of machine time, and process time. Therefore, those logistical key figures have a different relationship between each of key figures. Many writers distinguish them; they suggested that the strategic objectives derived from the market should be the foundation for the necessity trade-off between conflicting logistical goals for high utilization verse low WIP, see [16, 27].

2.1 Manufacturing Lead-time and Quick Response Manufacturing (QRM)

Nowadays, most of the manufacturing companies are trying to reduce their lead-times. Suri (2003) demonstrated that while manufacturing companies are trying to reduce their lead-times, most of the managers still support policies that will increase their company's lead-time [17]. In the report, Suri goes on to analyze why Lean Manufacturing principles do not work well in twenty-first century markets, and states the key characteristics used by QRM to develop a more viable concept called 'System Dynamics' . Most researchers that have studied and written on QRM in the last decade have built and extended built the techniques developed in numerous other previous process improvement methodologies, such as Total Quality Management, Lean Manufacturing, Re-engineering, Constraint

Management, and Six Sigma. Those statements will most likely be the foundation for the body of knowledge that will ultimately form the Agile or Flexible Manufacturing methodology. (For more details on key QRM characteristics, see [13, 17, 18]. Many of the quantitative models focus on the effects of MLT reduction on operational decisions such as batch size and quality (for detailed reviews, refer to [19]), while the others state that lead-time and demand are typically assumed to be an exogenous parameters (for more details, see [9, 8, 15]). The QRM theory includes the fundamental principles of manufacturing system dynamics, which provides insights such as the impact of management policies on the enterprise's lead-time." QRM achieves lead-time reductions by focusing on the management principles, manufacturing methods, analysis techniques, and tools that use basic concepts of system dynamics to reduce lead-time according to [17, 4]"..

2.2 Manufacturing Lead-Time (MLT) Formulation

Production consists of different processing and assembly operations. Aside from these operations, there are tasks related to material handling, inspections, and other non-productive activities. According to Hoopé and Spearman (2001) and Groover (2008), MLT is the sum of setup time, processing time, and non-operation time [9, 8]. Therefore, the activities involved in the process of production are divided into three main categories; the operation and non-operation elements in that category are explained in Equation 1. PLT is the sum of design time, manufacturing planning time, manufacturing control time, and MLT [9, 6]. The total time of each phase is the amount of time each function spends in completing its part of the job for a given product; this can be expressed by Equation 2. Q refers to the batch size and N is the number of processes needed to manufacture a product [6, 9].

$$MLT = n \cdot (T_{sui} + Q \cdot T_{oi} + T_{noi}) \dots\dots\dots(1). [6].$$

$$PLT = TPD + TMP + TMC + MLT \dots\dots\dots (2). [9].$$

(T_{oi}) is average operation time, while (T_{sui}) is average setup time and (T_{noi}) is average non-operation time, for the definition of (TPD, TMP & TMC) see Table 1.

Before taking any action or any simple strategic approaches to MLT reduction, PLT should be formulated under three interrelated elements:

- 1- Manufacturing system design should be coordinated with product design.
- 2- System and product design should be characterized by robustness and proper structures.
- 3- The operation of processes should be understood under a proper plan that ensures they operate with consistency and quality.

Three components of PLT (TPD, TMP and TMC) should also be controlled by accurate processes for each step of the processing system [9, 15]. Assuming all operation times, setup times, and non-operation times are equal for each manufacturing process. This research deals with the key methods for reducing

lead-time for those components of MLT which can lead to reduced lead-time in the manufacturing industry. assuming that the values of PL and MLT are available from Table 1, for instance, if you put PLT and MLT into a single pie chart, MLT will comprise 49% of the whole pie chart (for more details, see Figure 2). Table 1 also shows that MLT will take up 94% of the duration time of PLT (refer to Equation 2). This has been approved by several authors, as a major portion of the time is non-operational time because it depends on an average batch size, which is by parts. Thus, previous researchers have stated, “this is particularly important since 90–95% of the time spent in a factory is spent waiting (wait-time)” [8, 9]. MLT constitutes 94% of the duration of the product lead-time; therefore, it is the greatest indicator of production time and is a crucial subject to be studied. To see how MLT can be calculated, refer to Table 1.

Table 1. Calculations for MLT and PLT. Source: [6]

Time per item	Value	System (Lead-Time).h	Value
Processed through an average of six machines (n)	6	Manufacturing lead-time MLT .hours/item	4.2
Average setup time is by h (T_{sui})	5	Product Design Time (T_{PD}). hours/item	0.036
Average batch size is by parts	25	Manufacturing Control Time (T_{MC}). hours/item	0.2
The average operation time is min per item. (T_{oi})	6	Manufacturing Planning Time (T_{MP}). hours/item	0.014
Average non-operation time is h. (T_{noi})	10	Product lead-time(PLT) hours/item	
MLT= (5 + 25 *(6/60)+10) *6 = 105 hours/(25)batch by hours/item	4.2	PLT= $T_{PD} + T_{MP} + T_{MC} + MLT$ (PLT =0.036+0.014+0.2+4.2)	4.45

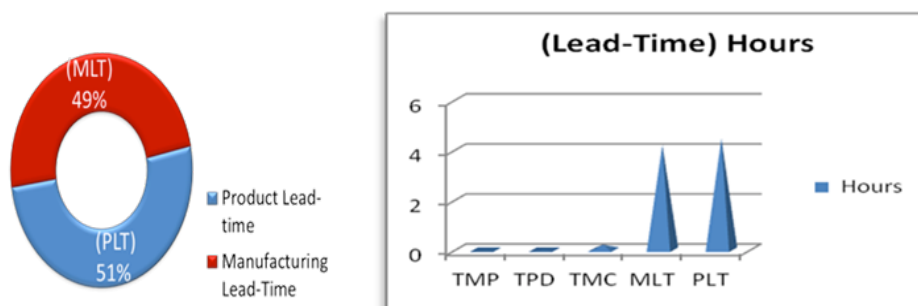


Figure 2. Approximate Contribution of MLT through the PLT Elements.

3. Technological characteristics of the type of manufacturing

MLT reduction is the optimal strategy when a firm thinks about lead-time reduction for each type of production such as; One-off, mass and batch production through the manufacturing process. The type of manufacturing depends on the volume of the production is broadly classified into three categories; one-off, batch production and mass production. The type of the manufacturing can be expressed by $K = O / P$ where O is the number of operations done in a month and P is the number of the working places, and depending on K the types of manufacturing. [9.19.23]. Technological characteristics of (One-off, Batch, & Mass) production are important factors to find a simple strategic approach to achieve lead-time reduction towards ZDM therefore; it should be a necessity to determine & understand the technological characteristics of them because they can lead to reduce manufacturing throughput time towards achieving ZDM. '(One-off - This is the oldest form of production. In that system, products made to satisfy a specific order. The order may be produced only once at regular time intervals to satisfy a continuous demand. While in the Batch production refers to the manufacturing process in which components or goods produced in groups (batches) and not in a continuous stream. This type depends on the size of the batches. While in the Mass production is the same, type of product manufactured to meet the continuous demand of the product. Usually demand of the product is very high and the market is going to sustain same demand for sufficiently long time)'. [9.23, 24]

3.1 Zero-defect manufacturing (ZDM)

Attaining perfect zero defects may not be possible, and there is always a chance of errors or defects occurring during the manufacturing process. Zero Defects (or ZD) was a management lead program that aimed to eliminate defects in industrial production and enjoyed brief popularity in America in the late 1960s and early 1970s. Quality expert Philip Crosby later incorporated it into his "Absolutes of Quality Management" and Crosby has repeatedly stated that defects occur due to management actions and attitudes [20, 21]. There has to be a certain manufacturing process in place that allows for the achievement of zero defects. Unless conditions are perfect, achieving the objective of zero defects is impossible. It is possible to measure non-conformance in terms of waste. Now it is a common manufacturing practice to try and reduce and minimize the number of defects, time, and errors in a process and to do things right the first time. The ultimate aim of ZDM is to reduce the number of defect products to zero. However, zero defects imply that there should be zero failures during operation, but not necessarily zero imperfections, blemishes, or non-conformities [21, 22]. The concept of zero defect manufacturing can be practically utilized in any manufacturing environment to improve quality and reduce time and cost. However, the implementation of zero defects requires the right conditions. There are two reasons to pursue zero defect quality products and processes: safety and customer expectation. Each step for

the general functional requirements of ZDM in this research has been summarized below:

- 1- Quality Assurance Standards: each step of the process should be undertaken in its proper manner and to its exact specifications. Corrections should be made before the next step is begun; thus, corrective measures will be able to minimize the negative impact of deviations from the step-by-step process.
- 2- Customs Inspection: each step in the manufacturing process is custom-designed and built to continuously inspect the procedure, thus assuring accuracy in manufacturing.
- 3- Manufacturing Assessment: Quick View (such as assessment questionnaires) is an assessment tool to find the problems and opportunities in the process of working towards zero defect manufacturing.
- 4- The survey questionnaire should be conducted through face-to-face interpersonal interactions, as this is the major technique for collecting information, opinions and data.

Experimental case studies should be used in order to understand the relationship between factors and which factors create a longer lead-time. They should also be used as sources of knowledge discovery for diagnosis and prognosis to help achieve ZDM.

4. Lead-time Reduction towards Zero Defect Manufacturing Methodologies

This section of the research study will examine the qualitative and quantitative research methods used. The qualitative research method permits a flexible and iterative approach, while the quantitative research method permits specification of dependent and independent variables and allows for longitudinal measures of the subsequent performance of the research subject [25]. The first stage of the procedure is survey-based research, as well as to identify the factors that have had the greatest impact on reducing lead-time. Therefore, choosing a survey-based on this research should be enquired towards zero defect manufacturing. The objective of the questionnaire was to gain insight into the manufacturing lead-time being studied, to identify the defects in the manufacturing industry (which are caused by an increased lead-time) and to identify improvement opportunities for reducing lead-time towards attaining zero defect manufacturing.

The second stage of the procedure comprises of experimental case studies. They should be designed according to analysis of the results obtained from survey questionnaires; these case studies should also be developed from previous case studies to provide a future framework in order to use a simple hypothetical manufacturing system to illustrate the basic factors (i.e., the main components of MLT) that determine manufacturing throughput time and explain why each factor occurs. Because inductive approach, which is relied on the

interpretive method such as survey procedure, a case study-experiment strategy and generalized the characteristics as well as the behavior of the investigated process from specific case findings? (see Figure 3).

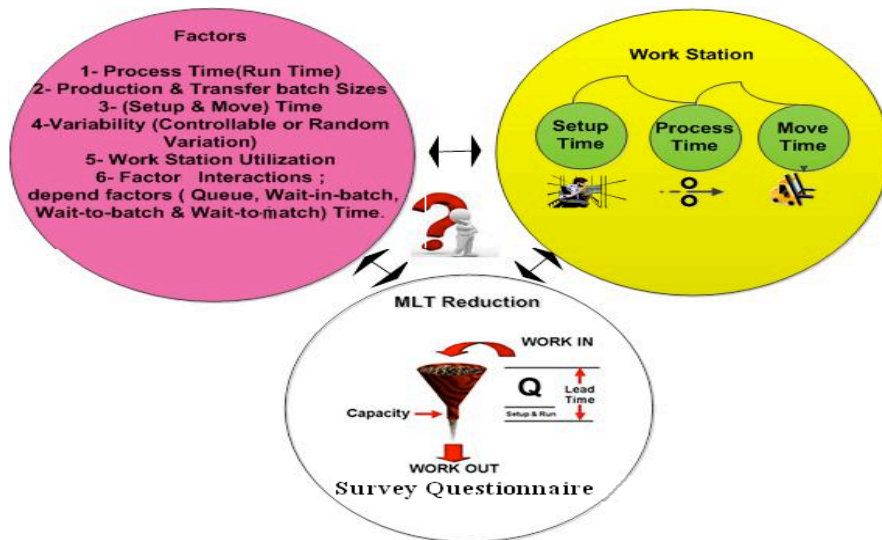


Figure 3: Road map of the research area

4.1 Survey Procedure

Interviews and questionnaires were the main instruments used to achieve the objective of this study. It was possible to conduct personal interviews because the sample was selected appropriately (there was no bias) and there were 17 questions prepared, which ensured the answers were in-depth and accurate. The interview is a face-to-face procedure that uses an interpersonal interaction to elicit answers pertinent to the research hypothesis; it was the major research technique for data collection in this study. 160 respondents were selected from the staff, based on their professional roles, and the samples were located across eight factories. The sources of the qualitative questions in this survey depended on the manufacturing assessment review; they included topics such as management practices, human resources, market management, manufacturing technology, operation management, quality management and maintenance. The assessment review has great impact on the manufacturing lead-time, and it is the major strategy of lead-time reduction towards attaining zero defect manufacturing. A survey study of the manufacturing assessment in Northern Iraq was conducted to evaluate and assess the performance of manufacturing systems. The assessment questionnaire is effective tool to help and understand the problems and opportunities confronting one's operations, also the survey questionnaire helps

knowledge discovery for diagnosis and prognosis towards achieving ZDM. The answers from the assessment questionnaire will help to:

- 1- Identify those areas of the manufacturing process that may need some attention.
- 2- Identify those areas for capital, defects, and time investment. It also identifies the causes of delays and defects that have made a great impact on lead-time reduction towards ZDM.
- 3- Highlight some of the non-technical parts of the manufacturing industry that may be impeding the company's growth and its competitiveness.
- 4- Highlight some of the following: the delay in obtaining raw materials; inefficient utilization of resources; expected late orders; statements are stated explicitly to the shortage of ability to work, cases involving variability of the workload; and the use of technologies.

Therefore, a survey questionnaire covers the general functional requirements of ZDM. (See the brief summary of result of the manufacturing assessment, conducted via survey questionnaire, in Figure 4 and Figure 5).

4.2 Experimental Case Studies

The future work is experimental case studies in order to find potential methods for reducing lead-time in the manufacturing process as well as identifies simple strategies for reducing lead-time towards ZDM. Choosing a multiple-case design is a hybrid exploratory–explanatory approach. The objective of the case study design is to gain insight into the manufacturing lead-time being investigated and to identify improvement opportunities for reducing lead-time towards ZDM. The case studies are based on questionnaire survey results also depend on a simple hypothetical manufacturing system to illustrate the basic factors that determine MLT and throughput time, because these case studies offer valid survey results, as well as on case studies related to the six factors in order to provide guidance for industry practitioners on how to reduce MLT towards an achieving ZDM. The factors are shown in Figure 3.

5. Results and Discussion

MLT is an indicator of production time and is 94% of the duration time of PLT, as shown in Figure 3. The responses to each question were assigned to the manufacturing assessment, which asked the respondents to answer the assessment questionnaire. The response rate was 100%. The summary of 160 responses indicates that all the participants have different primary functions. Among the 160 staff were 22 engineers, 54 technicians, 29 supervisors, 10 managers and 45 staff with different, unspecified jobs. The survey shows that 76% of them have experience of between one and three years and 24% of them have more than three years' experience. The level of experience and the participants' functions are the most important factors in their knowledge of the level of system

performance. In addition, these factors inform these staff members' opinions and suggestions to improve lead-time reduction towards ZDM.

Figure 4 shows that most of the eight factories have not provided enough professional training and feedback to employees and that most of them do not have enough Quality Assurance, Quality Control and Traceability in place in their company procedures. Only 13% of the participants mention fully supporting company procedures. Therefore, these statements provide the major direction for reducing defects in each step, measures which should be taken before the next step. 72% of the responses mentioned that the company maintained stock production. This affects decisions about batch size for products because 90% of respondents noted in the survey that the company informs their customers when orders are expected to be late. The researcher also asked respondents to rate their companies on job organization. 52% of respondents referred to an average situation and none of the 160 respondents mentioned an excellent situation. The assessment questionnaire shows that employees have a limited ability to work because they referred to serious shortages in the following areas: labor skill (69%); quality management and layout strategy for operation management (95%); planning for lot or batch sizes and the firm's policy (82%); and equipment, machinery and technology (88%). In addition, the respondents had limited current abilities, revealed by statements such as a high production rate every day, stock supply and/or in time deliveries, lack of communication on the workshop floor, and sudden changes in production/transfer batch size decisions, which were mentioned by 88% of respondents as being serious issues while 82% mentioned shifts not being scheduled regularly each day. Therefore, these areas of management practice, human resources and operation management have been identified as needing some attention and they should be improved before starting to reduce lead-time towards ZDM. Therefore, most of the statements indicated that the factories have not competes on quality, which means that defects and long lead-time could be expected during the process time.

Figure 5 shows the respondents' answers regarding the following factors which have a significant impact on MLT reduction and that should be targeted by their companies. The average rating of 4.7 indicates that the general sentiment among respondents is that process time has a major impact on lead-time reduction and their standard deviation is 0.30. This means that the largest average ranking indicates the top answer choice. Move time has an average rating of 4.4, indicating that the system performance needs a strategy for process and product layout procedure. Meanwhile, batch size, setup time, waiting time and time utilization received average ratings (3.8, 3.4, 3.4 and 3.3 respectively). Therefore, these factors have a major strategic role in reducing lead-time towards ZDM. They should be considered as guidance for future experimental case studies as well as guidance to industry practitioners on how to reduce lead-time towards ZDM. Since no organization can excel in all these factors simultaneously, the decision to focus

on one or more of these factors provides a unifying directional force for competitive advantage. If a firm competes on quality without defects and lead-time, then it should be evaluated in terms of its ability to deliver high-quality products in a timely fashion.

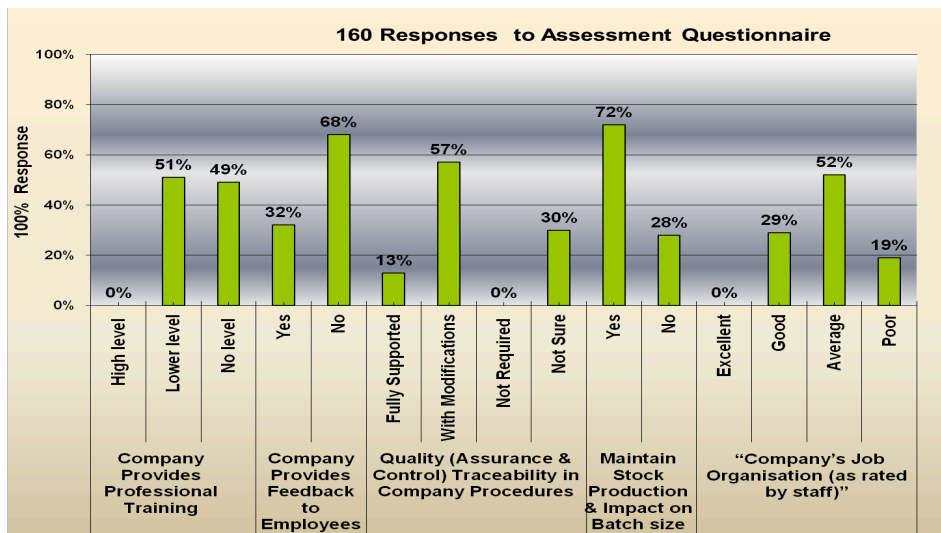


Figure 4 Responses to management practices and human resources assessment

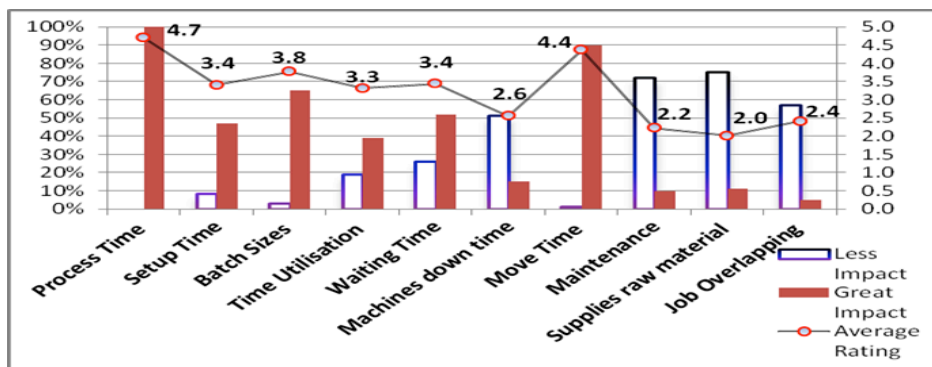


Figure 5 Factors that have a significant impact on lead-time reduction towards ZDM.

5. Conclusion & Future work

Nowadays, most companies attempt to improve quality management by reducing the opportunities for work to be damaged and shortening the time between manufacturing and defect detection. The researchers have identified the key methods for reducing lead-time towards ZDM. MLT is an indicator PLT. It should be considered a research area worth investigating. The Manufacturing Survey Questionnaire is one of the key tools for this purpose because

manufacturing assessment is an effective assessment tool for helping to understand the problems and opportunities of working towards ZDM. Therefore the inductive approach relies on the interpretive method. More specifically, the techniques that should be applied in this research work include a survey procedure in order to find the best opportunities for reducing lead-time. Future experimental case studies should be considered for six factors, altering each factor on the (Road Map) and will be designed in order to provide guidance to industry practitioners on how to reduce lead-time towards ZDM.

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