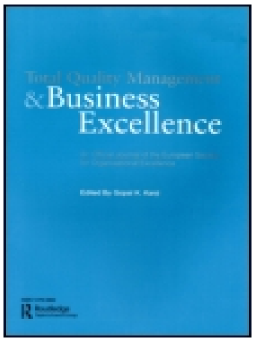


Total Quality Management & Business Excellence

ISSN: 1478-3363 (Print) 1478-3371 (Online) Journal homepage: https://www.tandfonline.com/loi/ctqm20

Implementation of the Lean Six Sigma framework in non-profit organisations: A case study

Chen-Yang Cheng & Pu-Yuan Chang

To cite this article: Chen-Yang Cheng & Pu-Yuan Chang (2012) Implementation of the Lean Six Sigma framework in non-profit organisations: A case study, Total Quality Management & Business Excellence, 23:3-4, 431-447, DOI: 10.1080/14783363.2012.663880

To link to this article: https://doi.org/10.1080/14783363.2012.663880

Total Quality Management
Vol. 23, No. 4, April 2012, 431–447

Implementation of the Lean Six Sigma framework in non-profit organisations: A case study

Chen-Yang Cheng* and Pu-Yuan Chang

Department of Industrial Engineering and Enterprise Information, Tunghai University, Taichung, Taiwan

The majority of Lean Six Sigma applications have focused on private industry, manufacturing and healthcare. It has not yet been applied to non-profit organisations (NPOs). The objective of most NPOs is to support public interest projects. To achieve this mission, most NPOs rely on charitable donations, which can be a scarce commodity. Ways to efficiently utilise scarce resources are usually overlooked. In the case study presented here, Lean Six Sigma tools and principles were used to increase the efficiency of resource management in physical disabilities services. A small machining shop that repairs, produces and customises devices for the physically disabled was the target; the goal was to make its production process more efficient. Use of DMAIC methodology decreased the non-value-added process by 70%. Finally, benefits of, experiences with, and extensions of Lean Six Sigma as applied to NPOs are discussed.

Keywords: DMAIC; Lean Six Sigma; non-profit organisation

1 Introduction

Lean Six Sigma combines lean production and Six Sigma to improve quality, reduce variance and eliminate waste. Lean production is based on two concepts: ‘just-in-time’ and ‘autonomation’. The goals are to eliminate process waste, shorten production time and increase process efficiency (Shah & Ward, 2007). Six Sigma is a quality-focused concept that aims to satisfy customer needs; it emphasises customer satisfaction and financial performance, reduces process variance and increases total participation (Brady & Allen, 2006).

The objectives of Lean Six Sigma are to rapidly improve customer satisfaction and quality, increase process speed and reduce costs. It is typically applied in manufacturing using DMAIC (Define, Measure, Analyse, Improve and Control) phases to improve product manufacturing processes. For example, Honeywell has utilised Lean Six Sigma methodology to reduce variance in casting quality and accelerate process speed (Antony, Swarnkar, Kumar, & Tiwari, 2006). In recent years, hospitals have also adopted Lean Six Sigma to maintain service quality and reduce costs (Vermaat, Koning, Bisgaard, & Heuvel, 2006). However, Lean Six Sigma has yet to be applied in the context of non-profit organisations.

As defined by Wolf (1990), non-profit organisations have the following five characteristics: an aim to serve the public; an organisational structure not oriented towards profit; a management structure that does not allow any individual to profit; legal standing as a tax-

---

*Corresponding author. Email: chengcy@thu.edu.tw

ISSN 1478-3363 print/ISSN 1478-3371 online

http://dx.doi.org/10.1080/14783363.2012.663880
http://www.tandfonline.com

exempt organisation; and legal standing that enables tax-deductible and tax-exempt donations to the organisation. Non-profit organisations are an important component of society. Hall (1987) defined the functions and impact of non-profit organisations based on cross-department interaction. Hall determined that non-profit organisations perform three different functions: provide public services as commissioned by the state; offer public services needed by society that the state and profit-driven organisations are unwilling to provide; and address policy directions that impact on state and profit-driven organisations or other non-profit organisations. Kramer (1987) suggested that non-profit organisations play four different roles in society: opening and innovating; reforming and guiding; protecting value; and providing services.

Non-profit organisations operate differently from typical profit-driven organisations. Non-profit organisations must rely on different activities and resource contributors to support their work. For example, a non-profit organisation may hold a charity benefit event to attract donations from individuals and companies. Therefore, the ability of an organisation to acquire and maintain resources is critical to its survival (Pfeffer & Salancik, 1978). However, most resources are inadequate and unstable, meaning that organisational work is constrained by resource contributors (Froelich, 1999). Under these circumstances, the appropriate utilisation of resources should be of great concern to non-profit organisations.

This study examined service-providing non-profit organisations. Non-profit organisations of this type typically provide services to recipients in critical need, necessitating the rapid provision of services to satisfy demand. For example, an earthquake measuring 9.0 on the Richter scale struck Japan in March 2011. After the subsequent tsunami 20,000 people were reported dead or missing. Northeast Japan suffered severe damage; most charity shelters lacked adequate resources. The international community provided assistance to Japan once the seriousness of the situation became clear, shipping relief supplies to Japan from around the world. To help those in dire circumstances, Japan had to distribute emergency supplies quickly and appropriately to disaster victims. Unfortunately, Japanese authorities did not distribute resources appropriately, leading to the deaths of many disaster victims. Clearly, the efficient and appropriate provision of limited resources is a crucial issue.

Section 2 of this study examines lean production, Six Sigma and Lean Six Sigma methods. Section 3 introduces the case subject for this study. Section 4 details the DMAIC phases (Define, Measure, Analyse, Improve and Control) when using Lean Six Sigma. The final section discusses research results and future research directions.

2 Literature review

Lean methods originated with the Toyota Motor Corporation. Such methods extend throughout the value chain, including production management, product development, supply chain management and customer service. Lean methods are not merely a tool for improvement, but are also a complete paradigm for corporate management, creating the greatest value for customers using the smallest investment possible (Womack, Jones, & Roos, 1990). Tools used in lean methods include value stream mapping, 5S (Sort, Segregate, Shine, Strengthen and Standardise), kanban systems, just-in-time (JIT), standardisation, the ‘5 Whys’, autonomation, and production levelling (Kumar, Antony, Singh, Tiwari, & Perry, 2006; Seth & Gupta, 2005; Su, Chiang, & Chiao, 2005). Production efficiency is increased and costs are decreased by excising waste that does not create value from the period spanning the receipt of customer orders to product delivery (Ohno, 2001).

Six Sigma was introduced by Bill Smith, a technician at Motorola, to address concerns about existing process defect rates that were significantly exceeding rates in final product testing, necessitating process improvements to reduce or eliminate errors (Brue & Launsby, 2003/2004). In recent years, Six Sigma has developed into a management philosophy based on a continual pursuit of improvement in customer-centric corporate strategic targets and product development standards (Pande, Neuman, & Cavanagh, 2000). Six Sigma involves the use of tools such as voice of the customer (VOC), quality function deployment, workflow diagrams, and cause-and-effect diagrams in five phases – Define, Measure, Analyse, Improve and Control – to pursue continual improvement in a cyclical fashion, thereby raising customer satisfaction and increasing profits.

As stated earlier, Lean Six Sigma combines lean methods and Six Sigma, using specific DMAIC processes to provide companies with greater speed and lower variance in increasing customer satisfaction (George, 2002). The first phase in DMAIC is Define, or defining project objectives and customer needs. The second phase is Measure, or measuring errors and process performance as well as quantifying problems. The third phase is Analyse, which involves analysing data and finding the causes of defects. The fourth phase is Improve, or correcting the causes of defects and reducing errors. The final phase is Control, or controlling the process and maintaining performance, thereby improving performance. These five phases can enable Six Sigma teams to systematically and gradually develop process rationalisation, beginning with defining the problem and then introducing solutions targeted to the fundamental causes, thereby constructing the optimal implementation method and ensuring the sustainability of solutions (George, Rowlands, Price, & Maxey, 2006).

Several examples of implementing Lean Six Sigma in the manufacturing industry are quite successful. Pickrell, Lyons, and Shaver (2005) presented two case studies for Lean Six Sigma projects of precision slip rings and integrated motion systems for high performance requirements in military and commercial aircraft, satellites and space vehicles, missiles, and automated industrial machinery. The results show that the Lean Six Sigma approach can reduce the costs, cycle time, customer returns and inventory, and increase production capacity. Chena and Lyu apply Lean Six Sigma to resolve the touch panel quality problem (Chena & Lyu, 2009).

In addition, Lean Six Sigma can also be applied in non-manufacturing industries including software development, service industries, education, administrative departments and material procurement. Furterer and Elshennawy (2005) presented a case study of applying Lean Six Sigma tools and principles to improve the quality and timeliness in a city's finance department. Koning, Verver, Heuvel, Bisgaard, and Does (2006) applied a Lean Six Sigma approach to help healthcare providers achieve quality of care for patients. However, there are only a few researches about implementing the Lean Six Sigma approach in non-profit organisations. Fiddick (2005) discussed applying Six Sigma in non-profit organisations to increase the efficiency of processes, increase customer satisfaction and reduce costs. However, there is no discussion on combining lean methods and Six Sigma in NPOs.

3 Non-profit organisation (NPO) case study

The subject of this study is the Assistive Devices Service Center for people with disabilities in Taichung City, Taiwan, managed and operated by the Maria Social Welfare Foundation. Products include various types of wheelchairs, walkers, child rehabilitation assistive devices and exercise therapy assistive devices. These products are provided to people with disabilities and members of the general public who are determined to be in need following an assessment.

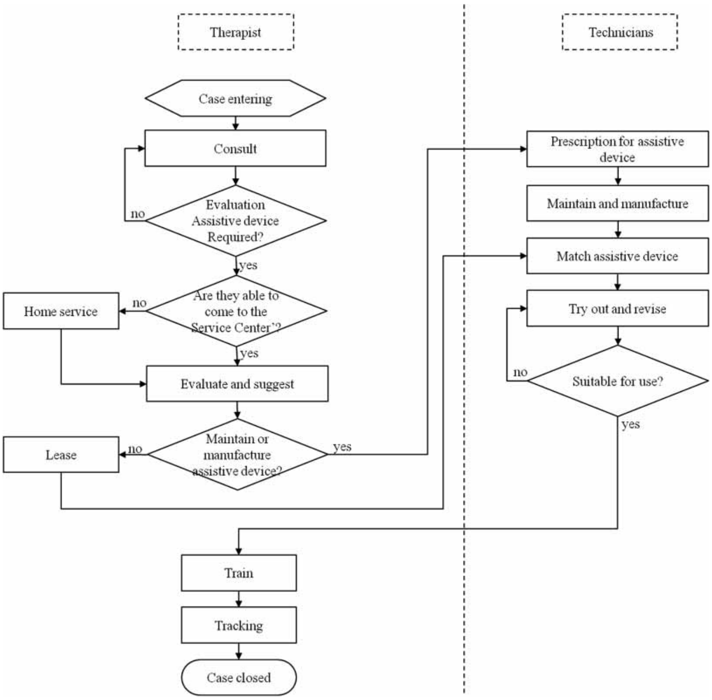


Figure 1. Service process flow.

The service process for this organisation is shown in Figure 1. When a case contacts the Service Center, therapists provide counselling services. In some cases, if a case cannot arrive at the Service Center in person, therapists can provide services at the case's house. Therapists assess whether cases need assistive devices or not. After evaluation, most assistive devices require customised manufacturing. Technicians design the customised devices according to the therapists' assistive device suggestions. Overall, therapists are responsible for managing individual case referrals and making assessments and assistive device suggestions. Assistive device technicians are responsible for enhancing, producing and modifying assistive devices to provide a complete service to people with disabilities.

The Service Center provides a diverse range of services and a significant range of products in small numbers. These products are categorised into two types depending on the acquisition source. The first type is products purchased using funds provided by the government or through outside donations. The second type is donated physical assistive devices, which are disassembled into individual components and then repaired and reassembled into products based on user needs. Some of these products utilise components donated by the public, which differ in terms of manufacturer, size and function. Under these circumstances, component types are numerous, making materials management exceedingly important. Lead time increases if components are not effectively managed, impacting on material preparation lead time and resulting in late delivery. These circumstances have led the Service Center to begin focusing on resource management problems and raise resource usage rates using Lean Six Sigma methods. Figure 2 offers an improvement framework diagram that achieves this goal.

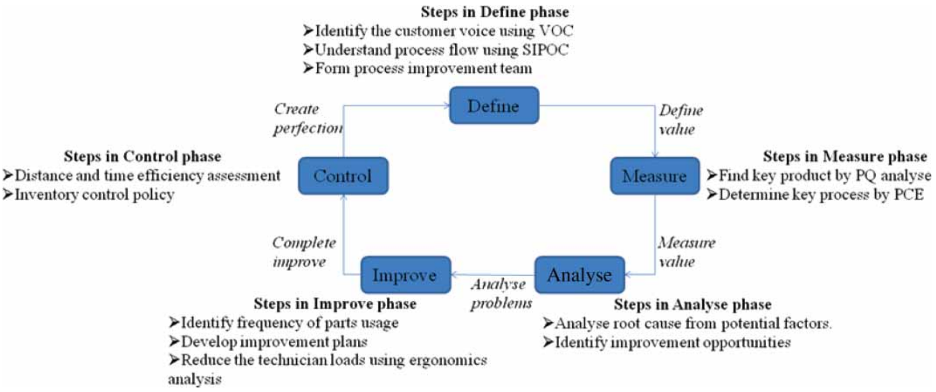


Figure 2. DMAIC framework.

4 DMAIC implementation

As noted earlier, DMAIC implementation consists of several phases: Define, Measure, Analyse, Improve and Control. Each of these is described as below.

4.1 *Define phase*

The goal of the Define phase is to define the project scope, the objective, and assemble an improvement team. Team members and the organisation have to reach a consensus on project scope and objective.

4.1.1 *Identifying the customer voice*

Through individual interviews with customers, this study determined whether the products provided by the organisation met the needs of people with disabilities, whether the products were durable, and whether the delivery time was too long, to determine customer reaction to the products overall. The results, as shown in Table 1, indicated that customers were dissatisfied with product delivery time, and technicians noted that components were difficult to locate, lengthening production time. Therefore, the project focused on production time at the machine shop.

4.1.2 *Understanding process flow*

The relationships between internal processes with external providers and customers can be understood by constructing a SIPOC (Supplier, Input, Process, Output, Customer) model.

Table 1. Customer voice.

Source	Customer type	Voice of the customer (VOC)	Customer need	Process output
External customer	Client	Excessive lead time	Receive product as soon as possible	Order to delivery time
Internal customer	Therapist	Overspending	Reduce expenditures	Cost requirements
Process participant	Technician	Difficult to find components	Storage area should be better organised	Production time

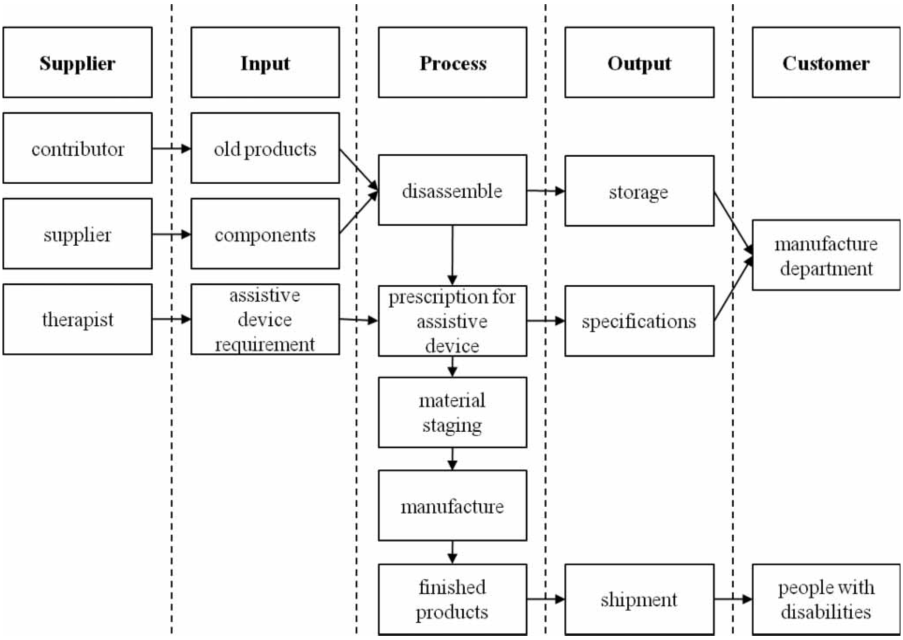


Figure 3. SIPOC model.

As shown in Figure 3, the objective of this project was to correct problems in the production process. As discussed in the preceding background information on non-profit organisations, efficient and appropriate allocation of resources to those in need is crucial. Additionally, service time must be reduced to a range acceptable for customers. However, since non-profit organisations do not prioritise earnings – instead, they aim to provide complete services to people with disabilities – this study did not include service time required to provide assessment, consultation and medical service suggestions to avoid infringing on the rights of service receivers. Project overview is shown in Table 2.

Table 2. Project overview.

Project name	Raising resource usage rate
Project period	15 August 2010 – 30 January 2011
Project leader	1 therapist
Project members	2 assistive device technicians and 8 volunteers
Scenario	Components are accumulated and stored in a disorganised fashion, leading to inconvenience and delays in component preparation and production
Problem description	As demonstrated by VOC, the problem results from an excess of components and a lack of planning, leading to delays in lead time and increases in stock
Project scope	Taichung City Assistive Device Service Center for people with disabilities
Project objective	Enable Service Center to appropriately utilise its resources with limited manpower through process re-planning, reducing lead time and decreasing warehouse stock
Expected benefits	Reduce lead time by 10%, raising quality of service provided to people with disabilities

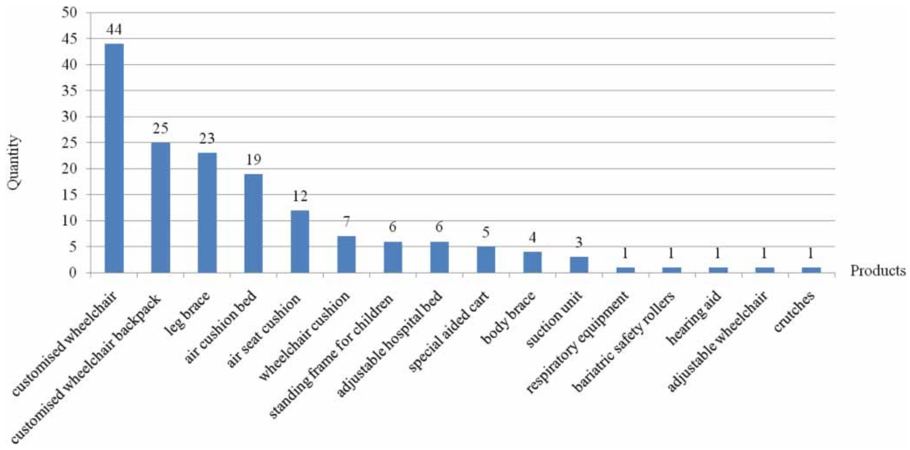


Figure 4. PQ analysis for the year 2008.

4.2 *Measure phase*

The goal of the Measure phase is to understand and document the current status of the processes to be improved. In this phase, the improvement team identified the customised wheelchairs as the primary product, and calculated the process cycle efficiency (PCE) to determine whether the processes were consistent with lean methods. The activities executed and methods applied during the Measure phase are discussed below.

4.2.1 *Find the primary product*

Use of product-quantity (PQ) analysis, as shown in Figure 4, to examine the average quantity of products produced each month revealed that most clients require customised wheelchairs – such requests constitute 30% of total product demand. Therefore, this project focused on customised wheelchairs as the primary product requiring operation time improvement.

4.2.2 *Collect information*

Since the materials for customised wheelchairs include both stainless tubes and stainless bars, as shown in the bill of material (BOM) in Figure 5, the project team collected information relating to machine shop layout and the manufacturing process for customised wheelchairs. Wheelchairs can be categorised into stainless tube type and stainless bar type. The manufacturing process of the stainless tube wheelchair includes material preparation operation, stainless tube operation, manufacturing operation and assembly operation. For the stainless bar wheelchair, the only difference is in stainless bar preparation operation. After detailing a value flow chart, the improvement team calculated the process cycle efficiency (PCE) to determine whether the processes were consistent with lean methods. The PCE calculation results for the stainless tubes and stainless bars at various stages in the process are shown in Table 3 and Table 4. The results indicate that the PCE of material preparation operations, stainless tube operations and stainless bar operations were less than 5%, and that non-value-added time was significantly greater than value-added time. Therefore, these two stages were the primary processes to be improved. The PCE model is shown in Equation (1). Non-value-added time

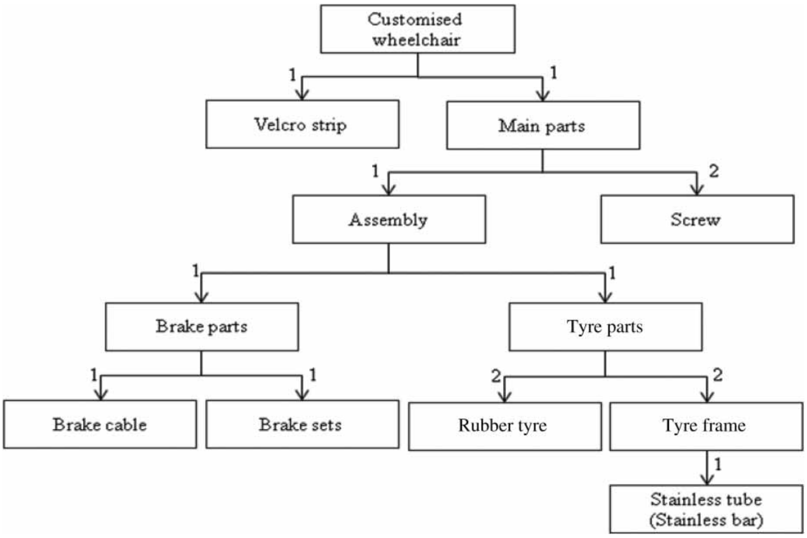


Figure 5. BOM of customised wheelchair.

Table 3. PCE for stainless tubes type wheelchair process.

Operation	VA	NVA	Cycle time	PCE (%)
Material preparation operation	30	430	460	0.5
Stainless tube operation	245	694	939	4.5
Maintain operation	1380	456	1836	26
Assembly operation	1685	356	2041	32
Total	3340	1936	5276	63

Table 4. PCE for stainless bar type wheelchair process.

Operation	VA	NVA	Cycle time	PCE (%)
Material preparation operation	30	430	460	0.6
Stainless bar operations	123	548	671	2.4
Maintain operation	1380	456	1836	27.5
Assembly operation	1685	356	2041	33.5
Total	3218	1790	5008	64

(NVA) is the time spent on steps that add product value to the finished product. It is also referred to as waste time. Value-added time (VA) is the opposite of NVA. Table 3 shows the PCE of stainless tubes process. The cycle time is VA time plus NVA time, and lead time is the sum of all cycle time. The smaller PCE means less in efficiency.

$$\text{Process Cycle Efficiency (PCE)} = \frac{\text{value} - \text{added time}}{\text{lead time}} \tag{1}$$

4.3 *Analyse phase*

The Analyse phase uses cause-and-effect diagrams and videotape analysis to identify various waste and non-value-added activities in the customised wheelchair production process. The goal is to identify root causes that are resulting in inefficiencies and errors. The fundamental reason for the problem was established via asking the 5 Whys. Then, a cause-and-effect diagram was used to list problems that could occur in the production process (personnel, operating procedures, storage rack and raw materials) to construct a complete system framework. During the brainstorming period, records of all ideas were retained to ensure no potential problems or solutions had been overlooked. The results are shown in Table 5. These potential factors can be summarised as material preparation operations, stainless tube operations and stainless bar operations. Since these operations are related to the storage rack, the improvement team will focus on storage rack arrangement.

Table 5. Potential factors.

	Factors (cause)
Material preparation operation	1. Inadequate manpower (personnel).
	2. Volunteers lacking training, hindering the identification of components (personnel).
	3. Quality, quantity and specification of donated components are unstable (raw materials).
	4. Items occupy walkways, hindering ability to walk and manoeuvre (storage rack).
	5. Components are stored in storage rack arbitrarily, hindering location of components (storage rack).
	6. The working area is significantly far from the components storage rack (operating procedures).
Stainless tube operations	1. 6-foot stainless tubes are haphazardly piled on the floor. When searching for and retrieving metal bars, the topmost metal bars must be moved to locate the target bars (storage rack).
	2. Previously cut stainless tubes must be stacked on top of the original tubes, requiring the technician to measure the bar length every time a tube is selected to determine whether the tube is of appropriate length (storage rack).
	3. Stainless tubes are stacked in walkways, hindering ability to walk and manoeuvre (storage rack).
	4. Technicians must kneel or squat to identify and retrieve stainless tubes located on the ground, increasing pressure on technicians' knees and backs (storage rack).
Stainless bar operations	1. 6-foot stainless bars are stacked against the wall. When searching for and retrieving the solid metal bars, the nearby materials must be moved to a safe place before locating the target (storage rack).
	2. Previously cut stainless bars must be placed in front of the original stainless bars, forcing technicians to measure their length each time an bar is selected to ensure it meets requirements (storage rack).
	3. If it is not reconfirmed that placement is safe, stainless bars may collapse and cause danger (storage rack).
	4. Stainless bars are located in the leftmost part of the machine shop, while the working area is on the rightmost part of the machine shop; therefore, transport distance is considerable (storage rack).

4.4 *Improve phase*

The goal of the Improve phase is to define improvement opportunities of material preparation operations, stainless tube operations and stainless bar operations. Over the course of this project, the improvement team will estimate, choose and strengthen the plan to ensure the objective is achieved.

4.4.1 *Define frequency of parts*

This study used 5S methodology of *seiri* to categorise the products and components into A, B and C levels according to their usage rate, define frequency of parts usage and to arrange the storage rack in order. Number of parts requirements and usage rates are shown in Figure 6. For example, the number of wheels is 121, and its usage rate is 20%. A-level parts have a usage rate of at least 10%, B-level parts have a usage rate of 2–10%, and C-level parts have a usage rate of 0.1–2%. The equation of ABC categorisation was as follows:

$$\text{Target product usage rate} = \frac{\text{Target product quantity}}{\text{Total product quantity}} \tag{2}$$

4.4.2 *Develop improvement plans*

The improvement team arranges the storage rack according to the result of PQ analysis of parts. The As-Is and To-Be arrangements of the storage rack are described as follows:

- The As-Is arrangement of the storage rack is shown in Figure 7. The ABC classification of parts revealed that A-level wheels were stored in different storage places, and other parts were also stored in a disorganised fashion. The As-Is machine shop layout is shown in Figure 8. The technicians' working area was located on the left side of the storage rack. Technicians take parts from the storage rack following dotted lines. Retrieving components required technicians to move to the right side of the storage rack, increasing time required to search for and transport components.

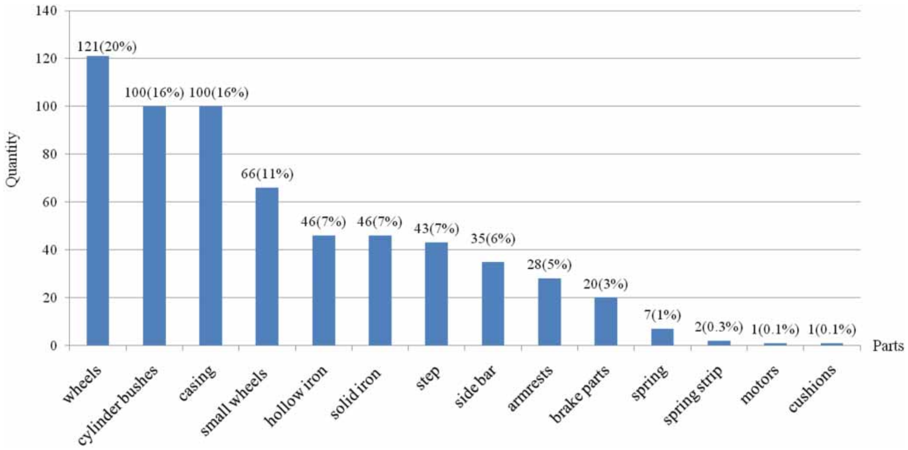
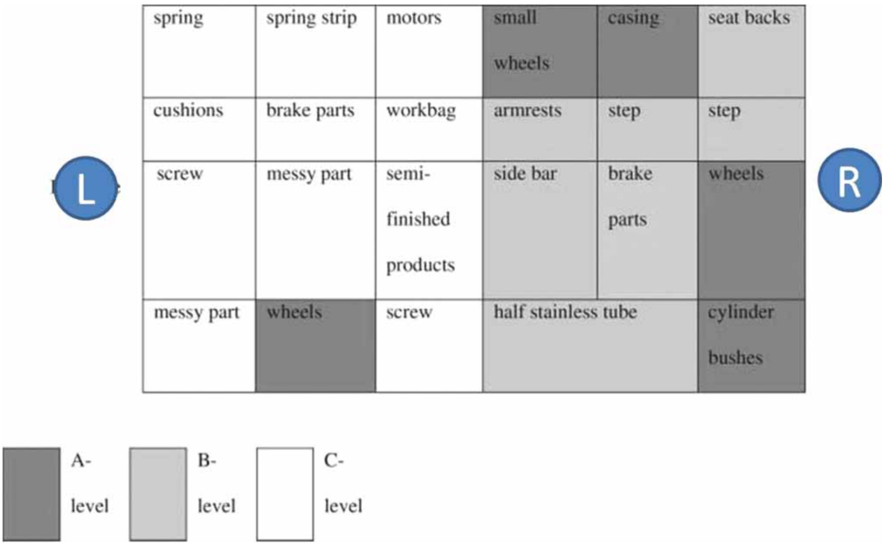


Figure 6. PQ analysis of parts in the year 2008.



spring	spring strip	motors	small wheels	casing	seat backs
cushions	brake parts	workbag	armrests	step	step
screw	messy part	semi-finished products	side bar	brake parts	wheels
messy part	wheels	screw	half stainless tube		cylinder bushes

Figure 7. As-Is arrangement of storage rack.

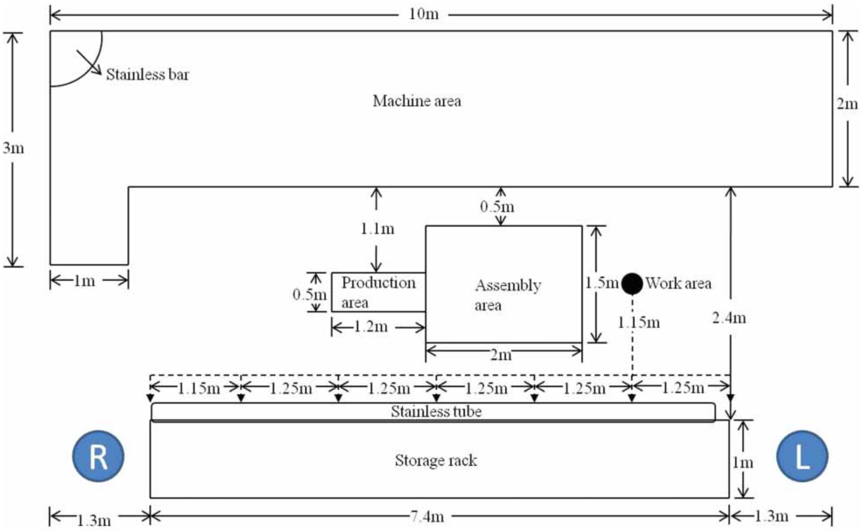


Figure 8. As-Is factory layout. (The notation R and L are mapping to the Figure 7 storage rack direction).

- The To-Be arrangement of the storage rack is shown in Figure 9. The improvements designated the topmost two rows for metal bars, while the bottom two rows were reserved for parts, reordered according to usage rates. For example, the most commonly used A-level products, wheels and bearings, were placed in the storage rack closest to the working area. These parts required the greater storage space in the storage rack due to their quantity. To effectively utilise the space, parts were stored on the bottom level. In addition, the least-used C-level components were stored far from the working area. Parts with a usage rate below C-level are moved out from the machine shop.
- The improvement team simulates the moving distance in the As-Is and To-Be arrangements of the storage rack; see Table 6. For example, if a technician wants to take A-level parts, wheels,

Table 6. Percentage of reduction in moving distance.

	Parts	Average estimated distance of As-Is arrangement (m)	Average estimated distance of To-Be arrangement (m)	Percentage reduction of moving distance (%)
A-level	Wheels	7.3	2.4	67
	Cylinder bushes	7.3	2.4	67
	Casing	6.15	2.4	61
	Small wheels	4.9	2.4	51
B-level	Stainless bar	8.4	3.65	57
	Stainless tube	3.65	3.65	0
	Step	7.3	4.9	33
	Side bar	4.9	3.65	26
	Armrests	4.9	3.65	26
	Brake parts	6.15	4.9	20
C-level	Spring	2.4	6.15	–
	Spring strip	2.4	7.3	–
	Motors	3.65	6.15	–
	Cushions	2.4	7.3	–

the moving distance is 7.3 m from the working area to the wheel storage location on the storage rack. In comparison, in the To-Be arrangement of the storage rack, the moving distance is 2.4 m, which is a reduction of 67%. The reduction rate in moving distance is presented in Table 6.

4.4.3 *Reduce the technician loadings using human factors and ergonomics analysis*

In the As-Is storage rack, metal bars were placed on the floor space in front of the storage rack, inconveniencing technicians using the storage rack. When retrieving metal bars, technicians were required to search for metal bars in uncomfortable positions, putting pressure on their knees and backs. In addition, this study determined that the height at which metal bars were stored affected the technicians' ease of locating and retrieving them. Simply relocating the metal bars higher was insufficient. Therefore, this project redesigned the height of the storage rack using ergonomic design to relocate the metal bars to a storage space at waist level, reducing pressure on technicians' bodies. As shown in Figure 10, the rear height of the storage rack is 175 cm, technicians on average measured 165 cm in height, while the top level of the storage rack fronts is less than 165 cm in height. The metal bars were relocated to technicians' eye level.

Additionally, the metal bars were categorised by material and shape for convenient retrieval. The figure showing a side view of the cabinets reveals that the top level is designed to divide bronze bars from black iron bars. The specific weight of bronze is 8.89 kg/m^3, while the specific weight of black iron is 7.85 kg/m^3. When the volumes are equivalent, bronze weighs 13 kg while black iron weighs 11 kg; therefore, the two materials can be differentiated by merely picking up the bars. On the lower level, the bars were further divided based on whether they had square or round metal plates. Specific metal bars could be retrieved by locating bars with the needed dimension from the side view of the storage rack (see Figure 11). Finally, each categorised area was marked using engineering tape, eliminating confusion for technicians searching for metal bars. Engineering tape was also applied to the storage rack corners to ensure safety.

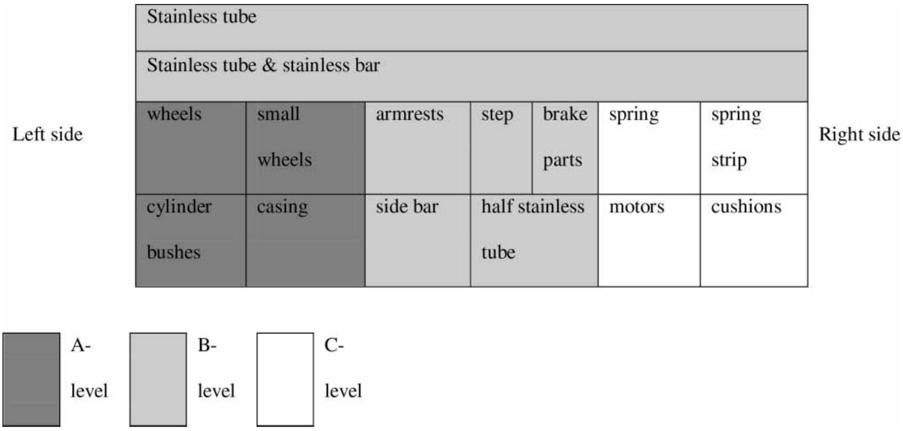


Figure 9. To-Be arrangement of storage rack.

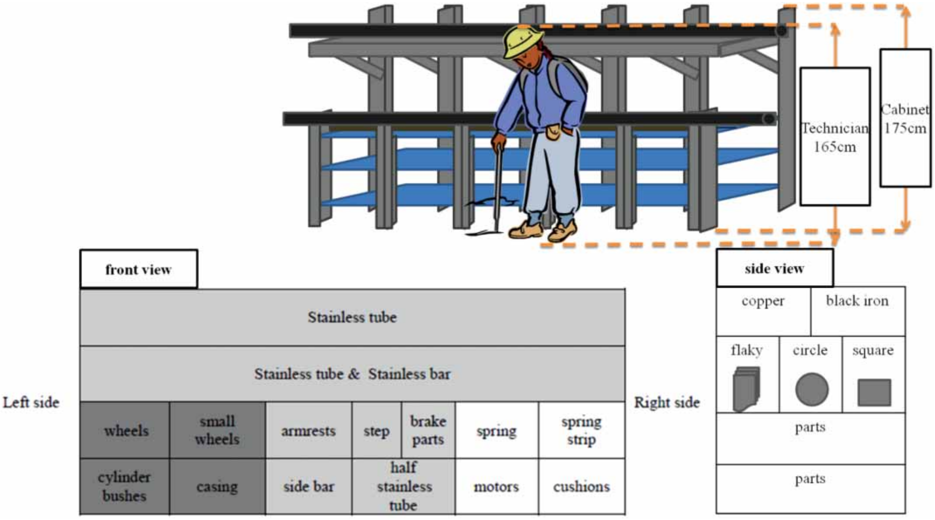


Figure 10. Improved storage rack design.

Figure 11. Metal bars categorised by shape.

4.5 *Control phase*

The goal of the Control phase is to implement performance measures and continuously improve.

4.5.1 *Improvement results*

After the implementation, the improvement team examined operations distances for the stainless tube and stainless bar processes by flow diagram, as shown in Table 7. The moving distance of the stainless tube process was reduced by 20% and the moving distance of the stainless bar process was reduced by 30%. This project substantially reduced moving distance.

Then, the production procedure for custom wheelchairs was measured again for time and distance to evaluate whether efficiency had been improved. The results indicated the improved storage rack design greatly increased the convenience of searching for and retrieving components. The distance between the storage rack and the technicians' work area was also reduced, significantly decreasing transfer and delay times. The overall improvements are shown in Table 8. The waste for hollow metal bars was reduced by 82% and PCE increased by 27%, while waste for solid metal bars was reduced by 84% and PCE increased by 28%, showing that this round of improvements yielded good results.

4.5.2 *Continuous improvement*

Standardised procedures, such as the replenishment policy shown in Table 9, were established after implementing the improvements described above. Previously, components were not stored using standard procedures, causing an over-accumulation of components and disorder at the site. Storage restrictions limited maximum and minimum component quantities based on monthly usage of each component, increasing the convenience of quantity control. The quantity of each component must remain between the maximum and minimum values. Additionally, components must be immediately replenished when

Table 7. Percentage reduction in process.

	Average estimated distance of As-Is arrangement (m)	Average estimated distance of To-Be arrangement (m)	Percentage reduction of moving distance (%)
Stainless tube process	28.23	22.48	20
Stainless bar process	22.56	15.82	30

Table 8. Assessment of efficiency comparing production process before and after improvements.

		Before improvement (seconds)	Improved (seconds)	Comparisons
Stainless tube process	VA	3340	3340	–
	NVA	1936	356	Reduce 82% waste
	Cycle time	5276	3696	Shorten 30% time
	PCE	63%	90%	Promote 27%
Stainless bar process	VA	3218	3218	–
	NVA	1790	285	Reduce 84% waste
	Cycle time	5008	3503	Shorten 30% time
	PCE	64%	92%	Promote 28%

Table 9. Replenishment policy in the storage rack.

Parts	Monthly usage	Maximum	Minimum
Cylinder bushes	4	8	4
Wheels	3	6	3
Small wheels	3	6	3
Iron	2	4	2
Step	2	4	2
Side bar	1	2	1
Armrests	1	2	1
Brake parts	1	2	1

their quantity drops below the minimum value, and should be managed to ensure quantity does not exceed the maximum value to prevent over-accumulation. This study will continue to observe the project and develop monitoring programmes to sustain continual improvement.

5 Conclusion

In the past, Lean Six Sigma was primarily used in factories. More recently, it has been applied to service-oriented government agencies and banks to improve their processes. Prior to this case study, this process had not been applied to non-profit organisations to improve efficiency. Non-profit organisations obtain the majority of their resources from the government or charitable donations and thus sometimes suffer from resource instability. They must also serve customers within a short period of time. Therefore, raising resource usage rates within a limited timeframe is a crucial goal for non-profit organisations.

To efficiently and appropriately allocate resources to customers, service time must be reduced to acceptable ranges. However, profits are not a priority of non-profit organisations; instead, they focus on providing complete services for people – in this case, for those with disabilities. The case study conducted for this research did not include time required for assessment, consultation and medical service suggestions provided by therapists to avoid infringing on clients' rights when improving production lead time.

Prior applications of Lean Six Sigma in factories had not focused on storage rack design, but storage rack design is closely correlated to lead time. The machine shop in this project, the Assistive Devices Service Center, only had a single large storage rack with numerous products in small amounts. Since a maximum of 10 products were produced each month, this project first conducted ABC categorisation of products and components based on their usage frequency. Products and components were categorised into different levels before the A-level products were collected and stored in the storage rack closest to the working area based on movement lines; labels were then affixed. Finally, from the perspective of human factor engineering, the 6-foot metal bars were stored on the top of the storage rack to allow for easy access by technicians, alleviating pressure on their waists. The metal bars could be identified from the side by their different coloration and shapes. Finally, minimum and maximum quantities of products were defined according to average monthly usage of each product, providing a basis for replenishing supplies and preventing the over-accumulation of components. Project results demonstrate that the appropriate design of storage rack can be crucial.

Following implementation, technicians could rapidly locate relevant components and enjoyed shorter transfer distances, reducing production cycle time. Therapists may reference these results when aiming to provide people with disabilities with faster services, increasing resource usage rates within a limited time and improving customer satisfaction. Overall, technicians and therapists are satisfied with the improvement result.

This case introduced the use of Lean Six Sigma in problem-solving situations involving disorganised components. Through use of the DMAIC method, this project reduced transfer and delay times, raising PCE by 27% and 28%. This project also developed storage restrictions to facilitate the effective management of stores, raising resource usage rates. Methodology and tools based on characteristics of non-profit organisations can provide a reference for individuals wishing to improve the efficiency of non-profit organisations' services.

References

Antony, J., Swarnkar, R., Kumar, M., & Tiwari, M.K. (2006). Design of synchronised supply chain: A genetic algorithm based Six Sigma constrained approach. *International Journal of Logistics Systems and Management*, *2,* 120–141.

Brady, J.E., & Allen, T.T. (2006). Six Sigma literature: A review and agenda for future research. *Quality and Reliability Engineering International*, *22,* 335–367.

Brue, G., & Launsby, R. (2003/2004). *Design for Six Sigma* (D. Huimin, Trans.). Taipei: McGraw-Hill.

Chena, M., & Lyu, J. (2009). A Lean Six-Sigma approach to touch panel quality improvement. *Production Planning & Control*, *20,* 445–454.

Fiddick, D.L. (2005). *Six Sigma for non-profit organizations* (EMGT 835 Field Project Report). Kansas: University of Kansas.

Froelich, K.A. (1999). Diversification of revenue strategies: Evolving resource dependence in nonprofit organizations. *Nonprofit and Voluntary Sector Quarterly*, *28,* 248–268.

Furterer, S., & Elshennawy, A.K. (2005). Implementation of TQM and Lean Six Sigma tools in local government: A framework and a case study. *Total Quality Management & Business Excellence*, *16,* 1179–1191.

George, M.L. (2002). *Lean Six Sigma*. New York, NY: McGraw-Hill.

George, M.L., Rowlands, D., Price, M., & Maxey, J. (2006). *The Lean Six Sigma pocket toolbook*. Taipei: McGraw-Hill.

Hall, P.D. (1987). *A historical overview of the private nonprofit sector*. New Haven, CT: Yale University Press.

Koning, H.D., Verver, J.P.S., Heuvel, van den J., Bisgaard, S., & Does, R.J.M.M. (2006). Lean Six Sigma in healthcare. *Journal of Healthcare Quality*, *28*(2), 4–11.

Kramer, R.M. (1987). *Voluntary agencies and the personal social services*. New Haven, CT: Yale University Press.

Kumar, M., Antony, J., Singh, R.K., Tiwari, M.K., & Perry, D. (2006). Implementing the Lean Sigma framework in an Indian SME: A case study. *Production Planning & Control*, *17,* 407–423.

Ohno, T. (2001). *Toyota production system*. Taipei, Taiwan: Corporate Synergy Development Center.

Pande, P.S., Neuman, R.P., & Cavanagh, R.R. (2000). *The Six Sigma way: How GE, Motorola, and other top companies are honing their performance*. New York, NY: McGraw-Hill.

Pfeffer, J., & Salancik, G.R. (1978). *The external control of organizations: A resource dependence perspective*. New York, NY: Harper & Row.

Pickrell, G., Lyons, H.J., & Shaver, J. (2005). Lean Six Sigma implementation case studies. *International Journal of Six Sigma and Competitive Advantage*, *1,* 369–379.

Seth, D., & Gupta, V. (2005). Application of value stream mapping for lean operations and cycle time reduction: An Indian case study. *Production Planning & Control*, *16,* 44–59.

Shah, R., & Ward, P.T. (2007). Defining and developing measures of lean production. *Operations Management*, *25,* 51–72.

Su, C.-T., Chiang, T.-L., & Chiao, K. (2005). Optimizing the IC delamination quality via Six-Sigma approach. *IEEE Transaction Electronics Packaging Manufacturing*, *28,* 241–248.

Vermaat, M.B., Koning, H.D., Bisgaard, S., & Heuvel, van den J. (2006). Standardizing healthcare projects. *ASQ Six Sigma Forum Magazine*, *6,* 14–23.

Wolf, T. (1990). *Managing a nonprofit organization in the twenty-first century*. New York, NY: Simon & Schuster.

Womack, J.P., Jones, D., & Roos, D. (1990). *The machine that changed the world: The triumph of lean production*. New York, NY: Rawson Associates.