IMPROVING THE EFFICIENCY OF OPERATING THE CONE LAYING AND COLLECTING MACHINE (C2L) USING TRIZ METHOD

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ABSTRACT: This article presents the process of redesigning the guidepost of Cone Laying and Collecting (C2L) machine, a semi-automated system that collects and lay cones. The guidepost in the first prototype, Phase 1 C2L, consists of multiple parts, which complicates the assembly and disassembly process, reducing overall operational efficiency. By redesigning the guidepost, this study aims to reduce the time and process steps when assembling and disassembling the guidepost, thereby improving its ease of use. By utilizing TRIZ's Trend of Flow Enhancement, the guidepost was redesigned as a singular foldable unit, eliminating the need to use screw to attach different parts together. The experiments showed that the new guidepost design reduced the time to assemble and disassemble by 92 % and reduced the process steps by half. This research not only achieved its intended objective but also highlights other potential advantages related to design simplifications. However, before it can be used under real-world operational settings, Phase 2 C2L still needs to be tested under actual working conditions so that any underlying issues can be identified and addressed.

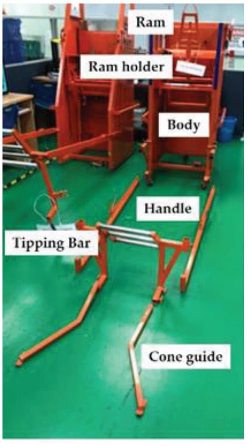
KEYWORDS: *Cone Collecting and Laying; TRIZ; Trend of Flow Enhancement; Machine Redesign; Efficiency*

1.0 INTRODUCTION

PLUS Malaysia Berhad (PMB) is the largest toll expressway operator in Malaysia and one of the largest in Southeast Asia [1]. Part of PMB's operation includes maintaining the expressway's assets (e.g., patching potholes, removing debris). The maintenance activities would usually require lane closure. This is to ensure that the workers can conduct their work within the enclosed area without stopping the traffic flow.

The lane closure uses safety cones as barriers, signaling highway users to not verge into the work area. However, this operation has one major concern, which is the safety of the workers. Currently, the workers manually lay and collect these cones, which exposes them to several safety hazards. When laying the cones, a worker walking on the pavement receives the cones from a colleague behind a moving lorry and places them in position. The collection process is done in reverse, where the worker gathers the cones and pass it to his colleague on the lorry that is moving in reverse.

The hazards that this procedure imposes on the worker, from the potential of being hit by live traffic, tripping and falling on the pavement to potential accidents with the reversing lorry, could not be understated. Considering the seriousness of each risk, it is important to find a safer and more efficient method to execute this task.



(a)

(b)

Figure 1: (a) Breakdown of Phase 1 C2L by parts and (b) Phase 1 C2L during operation

As an effort to tackle this issue, the Cone Laying and Collecting (C2L) machine was developed as a semi-automated system to replace the manual procedure of collecting and laying safety cones (Figure 1). By doing so, it aims to drastically reduce or altogether eliminate the workers' exposure to live traffic.

This research brings two novel contributions. Firstly, the initial C2L machine (henceforth be referred to as Phase 1 C2L), was designed so that the worker can execute this procedure from the back of a lorry, eliminating the need to walk on the pavement, thus reducing the exposure to the hazards mentioned above.

Secondly, the development of the Phase 1 C2L machine utilized the methodologies of TRIZ (The Theory of Inventive Problem Solving) in the design of the machine. TRIZ is a systematic approach to problem solving that is based on the idea that there are patterns and principles that underlie successful innovations. These patterns can be identified and used to solve a wide range of problems [2]. TRIZ has been widely adopted in manufacturing industries [3-5] and has been used to solve problems in a variety of fields as well [6-7]. TRIZ has also been shown to be a chosen tool in product development field [8-13].

Phase 1 C2L have shown that it can replace the manual cone laying and collecting procedure. However, there remains room to further improve its efficiency. One area of interest is the assembly and disassembly of the guidepost, which consist of 3 separate parts - the handle, tipping bar, and cone guide.

Thus, through this study, the objective is to optimize the design of the guidepost, to further improve its ease of assembly and disassembly, by leveraging on TRIZ methodologies. An improved guidepost design is expected to further improve the handling of the machine, resulting in increased efficiency of the overall cone laying and collecting process.

The ease of assembly and disassembly of the C2L machine with the new guidepost design (henceforth be referred to as Phase 2 C2L) will be compared to Phase 1 C2L. The result of this test will determine if the objective of this study is achieved. The findings from this study have the potential to set a new standard in highway maintenance practices, ensuring safety and efficiency in equal measure.

2.0 METHODOLOGY

The development of the new guidepost for the Phase 2 C2L was developed based on the principles of TRIZ which focuses on applying a series of systematic and logical principles, instead of executing trial and error tests. The flow of the experimentation is summarized in Figure 2.

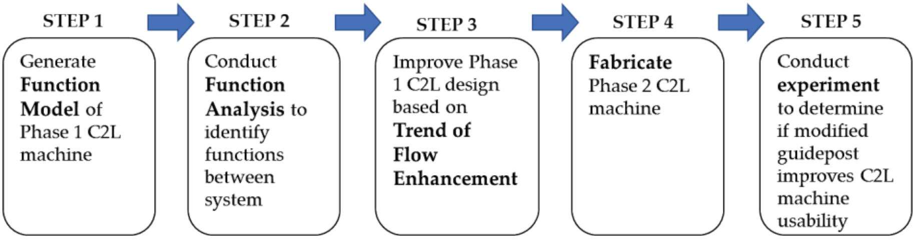


Figure 2: Flow chart of research methodology and experiment of research

In this research, three TRIZ tools were used. First, the Function Model and Function Analysis was executed to assign a Function to each of the system's component. Then, based on the recommendations from Trend of Flow Enhancement, selected Functions were adjusted to improve the conductivity of the assembling and disassembling process of the guidepost. The guidepost was redesigned and then fabricated. The new machine with the new guidepost design will be known as Phase 2 C2L. Both Phase 1 C2L and Phase 2 C2L were then tested under several parameters to determine if the new design managed to improve the ease of use in handling the guidepost.

2.1 Identifying Improvement Options Using Function Analysis (FA) and Function Model (FM)

The Function Model (FM) diagram for the Phase 1 C2L machine is shown in Figure 3. This tool helps to form a model that provides a conceptual description of a product or process [14]. By understanding the function of each component, ideas to optimize the function can be generated. On the other hand, the Function Analysis (FA) helps to analyze a process, where the Functions performed by different Operations within the process are compared and ranked by their functionality [15]. A Harmful function introduces temporary or permanent defects in the product/process, while a Useful Function contributes to the development of a product/process. Harmful functions within a system will be trimmed, while Useful functions generally will not be changed. The FA of the assembly and disassembly process of the guidepost (Table 1) showed that Harmful Functions was not identified within the process. Thus, no Function can be trimmed to ease the handling of the guidepost.

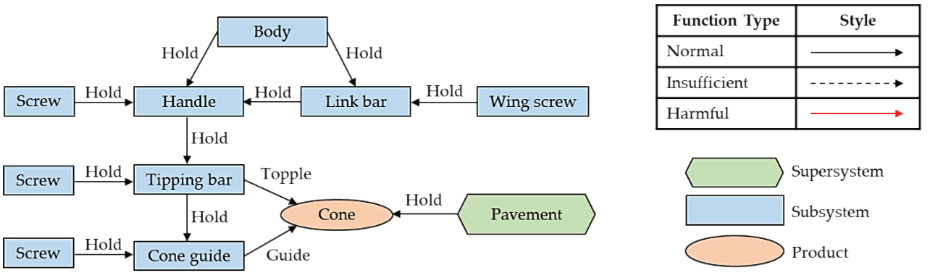


Figure 3: The Function Model (FM) of Phase 1 C2L machine

However, the guidepost assembly and disassembly process consist of *Providing Function (Prv)*, which are Functions that are necessary to complete the flow, but does not directly impact the Product (e.g., transport material, installation, measurement) [16]. In this case, adjustments and improvements to *Providing Function (Prv)* will be implemented to make the process more efficient.

Table 1: Function Analysis of the assembly process of the Phase 1 C2L guidepost

Operation	Activities (Function - Object)	Function Type
Assembling guidepost of Phase 1 C2L	1. Remove the screw that holds the handle to the body from its position	Prv
	2. Remove the wing screw that holds the handle link from its position	Prv
	3. Attach the handle to the C2L body, then secure it using a screw.	Prv
	4. Put the handle link to its position, then secure it by using a screw.	Prv
	5. Loosen the screw at the tipping bar.	Prv
	6. Insert the tipping bar into the end of the handle, the tighten the tipping bar screw.	Prv
	7. Loosen the screw at the bottom of the tipping bar.	Prv
	8. Install the cone guide to the tipping bar, then tighten the tipping bar screw.	Prv

2.2 Generate Idea To Redesign Guidepost

The ideation of potential solutions to redesign the guidepost to improve the ease of use was generated by referring to the recommendations under Trend of Flow Enhancement [16]. It introduces several steps that can be considered to design a process in an optimal way.

From the Function Analysis, we can see that the *Prv* functions impedes the efficiency of the flow, affecting the ease of assembling and disassembling the guidepost. To address these setbacks, 2 recommendations from the Trend of Flow Enhancement that focuses on increasing the conductivity of flow were selected (Table 2). Based on these recommendations, the idea to redesign Phase 1 C2L to improve its ease of use was generated.

Table 2: Selected solution to reduce the complexity of use of the Phase 1 C2L machine

Recommendations from Trend of Flow Enhancement	Specific Solution Ideas
• ***Establish an alternative route (bypass)*** Improve the flow by eliminating the need to assemble and disassemble 3 different parts • ***Boost the conductivity of individual segments of the flow pathway*** Join/connect different parts to make the assembly and disassembly process flow more smoothly.	To reduce the process steps to assemble and disassemble guidepost, the need to use screws to join different parts of the handle is bypassed. Instead, the guidepost was redesigned so that it becomes one large part where their movement is relative to each other, increasing the conductivity of flow.

The new guidepost was designed, then fabricated following the ideas summarized in Table 2. The new guidepost (Phase 2 C2L) consists of only one large part. Under this new design, the preparation time and process step to assemble and disassemble the machine is expected to reduce, thus improving the ease of use of the machine.

2.3 Experiment Setup

To determine the effectiveness of the new guidepost design, an experimental setup was formulated to measure the total time and the total process steps to assemble and disassemble the guidepost of both Phase 1 C2L and Phase 2 C2L.

By definition, an efficient system is one that can avoid waste of time and energy in an operation [17]. Hence, to determine if the objective of this study is achieved, the reduction of the waste of time, which is the time and the process steps to assemble and disassemble the guidepost between the 2 machines, was compared.

For the first parameter, the time to assemble the guidepost will be recorded using a stop watch. One person will assemble and disassemble the guidepost from each machine for 3 runs, while another person will record the time. The median of total time to execute each task were then tabulated and compared.

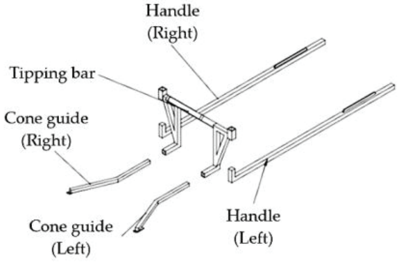
For the second parameter, each process step to assemble and disassemble the guidepost of each machine will be recorded. The number of steps taken by each machine were also compared.

The comparison data between Phase 1 C2L (old design) and Phase 2 C2L (new design) will determine if the redesign of the guidepost will increase the ease of use of the Phase 2 C2L machine.

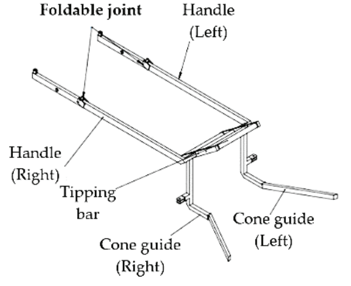
3.0 RESULTS AND DISCUSSION

3.1 Conceptional Design And Fabrication

The old and new design of the guidepost are shown in Figure 4(a) and 4(b). Originally, the old guidepost consists of 3 different parts - the handle, the tipping bar and the cone guide. All these parts were connected using screws. Following the guidance from Trend of Flow Enhancement [16], these parts were redesigned to make it into one large part, where the need to connect and disconnect the parts were bypassed.



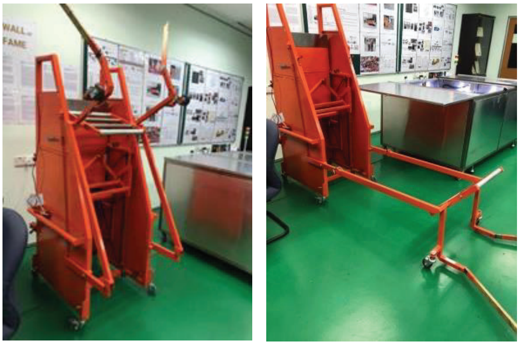
(a)



(b)

Figure 4: The design of the (a) old guidepost (Phase 1 C2L) and (b) new guidepost (Phase 2 C2L)

Each part of the old guidepost needs to be stored separately when not in use. This incurs additional handling of the machine. On the contrary, the new guidepost can be easily folded when not in use, and easily folded open prior to being used (Figure 5). This makes the Phase 2 C2L easier to store as a whole unit. On top of that, it also is easier to handle and assemble.



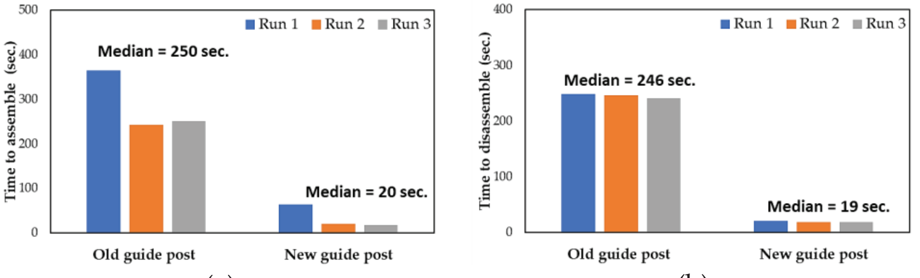
(a) (b)

Figure 5: The guidepost of Phase 2 C2L (a) folded during storage and (b) open prior to being used

3.2 Effect Of New Guidepost Design On Improving The Ease Of Assembling And Disassembling The Guidepost

3.2.1 Total Time To Assemble And Disassemble Guidepost

By redesigning the guidepost, the total time to assemble the guidepost reduced from 250 seconds to 20 seconds. Similarly, the time to disassemble the guidepost also decreased from 246 seconds to 19 seconds. The result showed the new guidepost is 92% faster to assemble and disassemble than the old guidepost (Figure 6).



(a) (b)

Figure 6: Comparing the total time to (a) assemble and (b) disassemble the old guidepost and new guidepost

The significant reduction in the assembly and disassembly time can be attributed to the elimination of the need to manually attach and detach different parts of the guidepost prior to and after being used. It takes extra time to attach and detach different parts of the old guide post together. However, this constraint does not exist on the new guidepost, as it is a single foldable part, hence the shorter assemble and disassembly time. The new guidepost design would also have a positive impact on the machine's setup time. Setup time is defined as the total duration needed to assemble a workstation, which includes the assembly process of a machine to run an operation [18].

One research reported that an extended setup time can lead to increased operational downtime, during which the process remains non-operational while waiting for machine setup [19]. A shorter setup is not only desired for improving efficiency [20], but it also enhances process responsiveness and flexibility in the production process [19]. In that sense, reducing the process steps to assemble and disassemble the guide post can be seen as a step towards achieving an optimal setup time.

3.2.2 Total Process Step When Assembling And Disassembling The Guidepost

The assembly of the new guidepost can be completed in 4 process steps, as opposed to the old guidepost design which takes 8 process steps (Table 3). The reduction of process step is made possible by eliminating the need to slot different parts of together and tightening it with screws. Eliminating this process significantly reduced the steps to assemble the guidepost, which explains why it was possible to obtain significant reduction in total time to assemble and disassemble the guidepost by 92%, as reported in 3.2.1.

Table 3: Comparing the process step of assembling the guidepost

Old Guidepost (Phase 1 C2L)	New Guidepost (Phase 2 C2L)
1: Remove the screw that holds the handle to the body from its position	**1**: Take out lock pin at the middle of the guide handle.
2: Remove the wing screw that holds the handle link from its position	**2**: Push down the handle at both sides of the C2L body
3: Attach the handle to the C2L body, then secure it using a screw.	**3**: Pull guidepost outward from folding position
4: Put the handle link to its position, then secure it by using a screw.	**4**: Put back the lock pin at the middle of the guide handle.
5: Loosen the screw at the tipping bar.	
6: Insert the tipping bar into the end of the handle, then tighten the screw.	
7: Loosen the screw at the bottom of the tipping bar.	
8: Install the cone guide to the tipping bar, then tighten the screw.	

On top of improving process efficiency, eliminating additional process steps may also contribute in other aspects. For example, More et al. discussed how substantial reduction in assembly time would lead to reduced worker fatigue [21]. As assembly and disassembly process is a manual process, reducing the process steps would incur lesser body movements. As a result, the worker would be less fatigued, leading to an increase in worker efficiency. Another research also discussed how reducing the variations in process time by reducing assembly steps may also lead to decreased human error [22]. Thus, by minimizing assembly and disassembly process steps, a more consistent and low-error process can be expected.

4.0 CONCLUSION

The objective of this study, to improve the ease of assembling and disassembling the Phase 2 C2L guidepost by leveraging on TRIZ methodologies, was successfully achieved. Compared to Phase 1 C2L, the redesigned guidepost demonstrated reduction in both the total time and process step to assemble and disassemble. Since the Phase 2 C2L can be set up and dismantled faster, the total operation time to lay and collect cones are expected to also decrease. These improvements further enhance the overall efficiency of the new C2L machine. Moving forward, Phase 2 C2L needs to be tested under actual working conditions so that any underlying issues can be identified and addressed before it is ready to be used by PMB.

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AUTHOR CONTRIBUTIONS

M. Reza: Fabrication, Experiment, Data Curation, Data Analysis, Original Draft Preparation; M.A. Salim: Conceptualization, Methodology, Fabrication, Result validation, Reviewing and Editing, Supervision; N.A. Masripan: Conceptualization, Fabrication, Result validation, Reviewing and Editing, Supervision; N.M. Yusof: Supervision.

CONFLICTS OF INTEREST

The article has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its submission and declare no conflict of interest on the article.

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