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Development and Simulation Via Flexsim for Kitting Trolley Design of Rear Car Seat Assembly Process

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ABSTRACT

It was discovered that the material retrieval system used for a Sweden brand car seats assembly lines (RB40% and RM60%) in a local seat assembly company was not systematic in its arrangement of the assembly parts and only had a rack trolley that carried all the assembly parts in a poly-box, thus affecting the productivity. Although kitting trolleys implementation was generally known to help pre-kit earlier at logistic/warehouse department, the fabrication cost and long-term benefit would be affecting company decision to implement kitting trolley in the production line. Thus, CAE analysis for layout and process simulation specifically the kitting process would help company to determine impact of trolley implementation towards productivity. The study aims to design kitting rack specifically for RB40% and RB60% assembly line and to investigate the kitting implementation effect toward productivity through FlexSim simulation.Project started from feasibility study of existing kitting rack trolley in market to conceptual design to detailed design and simulation analysis. Detailed design of the kitting trolley was produced and from the design, time study showed that assembly process per carseat was reduced. The current Flexsim kitting trolley simulation predicted improvement of productivity could be improved from 87.5% (current practice) to 91.2% for RB60% assembly. Nonetheless, both showed improvement of hence improving of quantities hence increase company's productivity and eliminate waste of time.

Keywords: kitting, productivity, CAE, Flexsim

Abbreviations

CAE	computer aided engineering
RB40%	rear back 40%
RB60%	rear back 60%
OSHA	Occupational Safety and Health Administration
secs	seconds

1.0 INTRODUCTION

Kitting is frequently discussed with in-plant material supply, as it has several advantages over the more traditional continuous supply principle which known as line-stocking [1]. It is the process of grouping components with dissimilar part numbers into kits prior to their delivery to assembly stations. In mixed-model assembly, different assembly objects generally require different kit contents. Thus, each kit is constructed in such a way that its contents correspond to a particular assembly object [2]. In production line, a kitting trolley that consists of metal shelves equipped with rollers or wheels that are used to transport components from one area to other area. It is used on the assembly line as a temporary storage location for components or parts to pick up components or parts for assembly processes as simple as possible for the operator [1]. The components are sorted and put in smaller box (pre-arranged kits) for a single assembly object. The kit may be displayed in a fixed position at an assembly station or, in the case of assembly along an assembly line; it may accompany the assembly object along the production line [1]. By implementing kitting, spaces consumed by components/parts at assembly stations and material handling of the assemblers could be reduced hence able to improve assembly operations and possible potential for quality improvements.

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Thus, numerous studies were done to study the effectiveness of kitting process on productivity. According to [1], significant cycle time reductions were observed on the installation of a car's front and rear doors. The result showed that kitting reduced the cycle time for assembling one pair of doors from 13 to 8 minutes, which showed 63% increase in productivity [1]. Moreover, study by [4] reported that working in progress (WIP) for mixed model frame was reduced from 2956 to 2070 units per day, saving to 886 units per day when lean kitting was implemented on the assembly line. Meanwhile, [4] reported reduction of cycle time for welding workstation from 80 minutes to 40 minutes while for the coating powder workstation reduction from 100 minutes to 45 minutes. Nonetheless, the studies were done based on observation and implementation on the actual production line. The Covid 19 pandemic has affected Malaysia's manufacturing industries thus companies are more careful in investing money to improve facilities for better production conditions. This is where CAE could help by simulating the kitting trolley design prior to actual fabrication.

A simulation is defined as a visual and functional replica of a real-world system. Simulating a manufacturing system is a virtual way of studying it without conducting actual experiments [8]. This visual validation can help in optimizing the systems and could help to present clear picture for management to determine if an investment is beneficial or not [9]. As a result, it is predominantly used in manufacturing, transportation, and service sectors to achieve beneficial outcomes such as reducing production cost and waste of time[5]. For instance, a case study was conducted utilizing the FlexSim software to observe a time study analysis of the healthcare system and concluded that 80% waiting time to receive treatment could be reduced by adding another registration counter as shown in the simulation[6].

In campus dining service, Kambli et al. [11] stated that discrete event simulations model analysis showed 45% of reduction in waiting time thus could enhance the operation management of a campus meal. According to the simulation, reallocation of unused servers could boost performance in crucial areas and minimize wait times. Meanwhile, in manufacturing, the simulation model could optimize machine performance, material flow, and process sequence. Zhu et al. [19] used Flexsim to identify bottleneck and idle resource in cold chain food logistics distibutions. A study by [10] examined the implementation of kitting on an automotive assembly line of a local automotive manufacturer using the computer-aided manufacturing software Delmia Quest. The outcome demonstrates an improvement in the assembly line's cycle time, inventory level, and space utilization. The cycle of time spent at work is intended to be reduced by 2.83%.

In the rear car seat assembly for Sweden car models, current production could not meet the daily target production which is 24 seats per day. The workers only managed to make 22 or 92.3% in productivity for RB60%. 12 plastic components for RB40% car seats and 10 components for RB60% car seats assemblies were delivered in poly-box from warehouse department and was put on rack adjacent to the assembly area. The components were always mixed as the poly-box did not have slots to separate the components. The assembly line workers had to take more time in identifying and segregate each component to pre-kit them before assembly for faster assembly process. In addition, they need to spend time to walk back and forth to obtain the components from the rack. Reducing/eliminating time that is not related to doing the assembly work could help in increasing productivity. Thus, kitting trolley was proposed to be used to minimize travel time to obtain components and non value added activities to pre kit components prior to assembly task, where warehouse workers have to pre kit/arrange the components before reaching assembly lines.

Nonetheless, fabrication and implementation of the the trolley would incur some cost and uncertainty of productivity improvement. By simulating the productivity prior to trolley fabrication, it would help company to predict productivity. As mentioned by [20], Flexsim is a software that supports all known modeling methods (discrete, continuous, agent, statistical). It is a robust software used in manufacturing sector and also in other sectors such as healthcare, warehousing, supply chain as well as for education purpose.Furthermore, some known companies such as FIAT used the software for production line optimization. Furthemore, the easy usage (drag and drop model building) would allow faster simulation learning process.[3] In addition, use of CAE analysis for layout and process simulation specifically the kitting process are rarely applied in Malaysia industries scenario. Therefore, this study intends to design kitting rack specifically for RB40% and RB60% assembly line and to investigate the kitting implementation effect toward productivity through FlexSim simulation. It is hypothesized that designed kitting trolley usage would increase productivity and meet 100% productivity.

2.0 METHODOLOGY

Fig. 1 shows the flows for this study and is critical to follow the steps precisely to ensure that this study runs smoothly. The process will be explained further in detail.

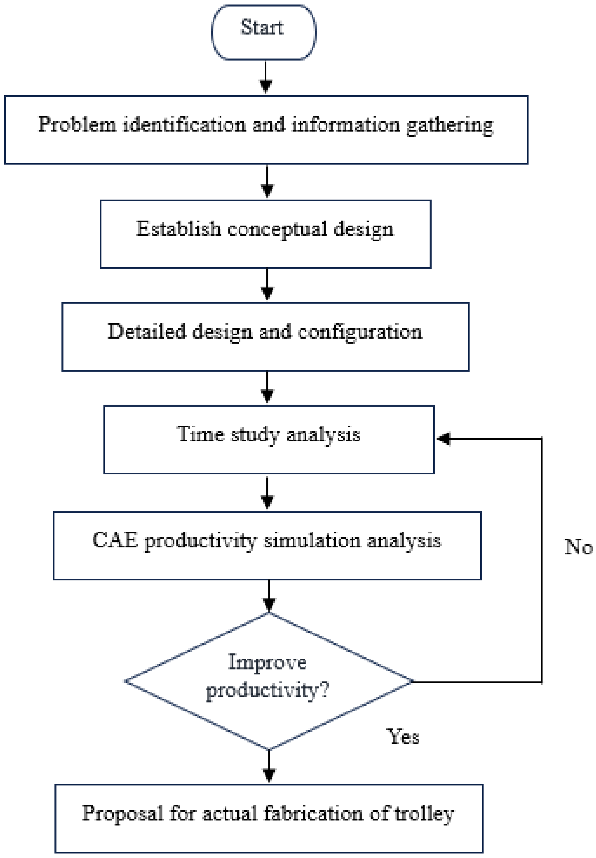


Figure 1. Current rack and kitting system by using blue poly-box

2.1 Problem identification and information gathering

In current practice at the production plant, the warehouse workers were responsible to perform kitting process and deliver to production line. As no proper kitting rack is used during kitting process at the warehouse, the workers used the normal rectangular shaped poly-boxes as storage container for the plastic components and the trolley as a carrier for the poly-box during delivery from the warehouse to the production line (Fig. 2). The poly-boxes were then stored on the rack adjacent to the assembly area.

As the boxes did not have any slots inside and the warehouse workers attitude to just put the components in the box with no proper arrangement, the components were always mixed up. When the boxes were delivered to the assembly line under that condition, the assembly lines workers faced difficulties in identifying the plastic components. Moreover, insufficient components problem is another issue also always happened. With these issues occurred, the assembly workers had to spend extra time to sort and count the components at the assembly line thus wasting the time that could be used to assemble more rear seats. To solve this problem, pre-assembly of components or parts should be done to ensure that operators have all the necessary items readily available when components reach their Point-of-Use. This would reduce downtime and improves workflow. Next, further interviews with assembly-line workers, data collection in the study area, and observing existing kitting rack system that was currently being used at another production line in the factory as benchmark were done to gather detailed information. The feasibility study of product assembled in investigated production line was conducted by examining the plastic components according to the bill of material and conducting a site visit to the warehouse to measure the dimensions of the components. All components were measured to be the base dimensions of the kitting rack design and to determine required slots quantities.

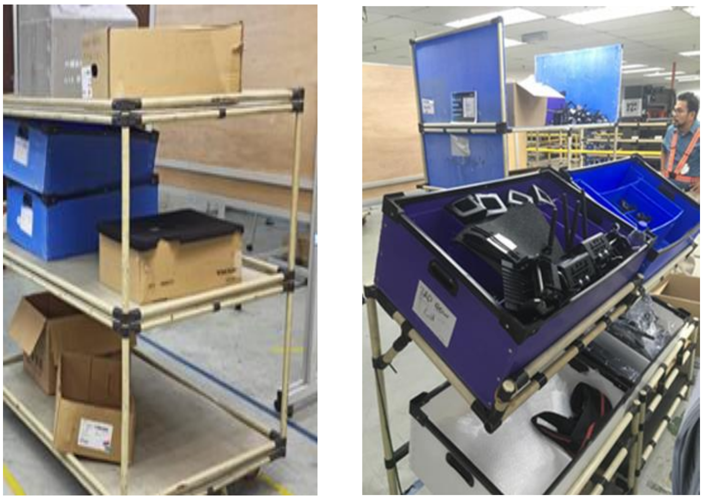
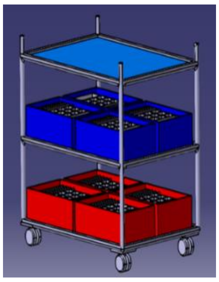


Figure 2. Current rack and kitting system by using blue poly-box

2.2 Conceptual designs

Three conceptual designs were made based on critical dimensions of RB40% and RB60% components. Apart of dimensions, materials and hardware of the kitting rack systems were also must be considered in designing the physical configuration of the kitting rack. To choose the best design, the Pugh chart analysis was performed. Pugh chart is a comparison tool that provides a holistic view of needs, goals and other critical criteria compared to the alternatives available. Table 1 showed the design concept and how the designs were benchmarked with existing rack based on listed criteria such as durable, portable and others.

Table 1: Concept selection via Pugh chart

Description	Current rack used	Trolley shape form with new poly-box partition	Slotted space kitting rack (Design RB60%)	Slotted space kitting rack (DesignRB40%)
Design				
Criteria	Datum	Design 1	Design 2	Design 3
Durability	0	+	+	+
Portability	0	0	+	+
Complexity (manufacturing)	0	+	-	-
Efficiency	0	-	+	+
Cost	0	+	-	-
Aesthetic	0	-	+	+
User friendly	0	-	-	+
+		3	4	5

2.3 Detail design and configuration

From the Pugh chart, the kitting trolley design were drawn using CATIAV5R20. The kitting trolley featured multiple slotted spaces and a wheel to facilitate the trolley's movement around the rear assembly section and entire slotted spaces were dedicated to store plastic rear-back components. The slotted space's dimensions were determined based on the largest dimension of largest plastic components. Additionally, the kitting trolley could transport eight sets of rear back components set to the assembly line. The slots configurations were based on the current existing kitting trolley used by Japan car's production line in the at the same company as the Japan car trolley already fulfils all OSHA safety requirements. The kitting trolley were made in two configurations to accommodate 60% side and 40% side assembly components (Fig. 3 and Fig. 4).

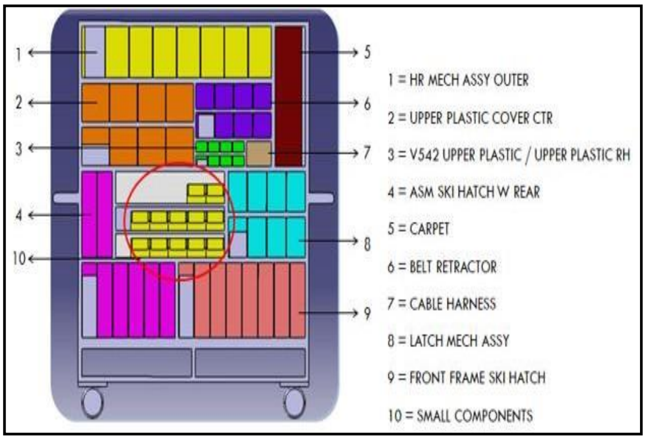


Figure 3. Kitting trolley configuration 60% (RB60%) side kitting rack

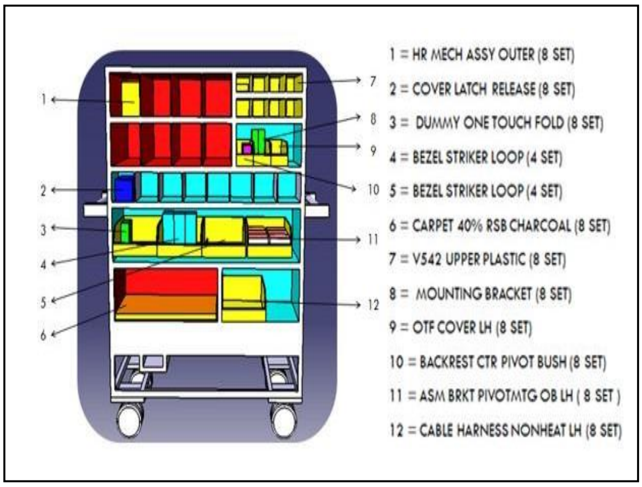


Figure 4. Kitting trolley configuration 40% (RB40%) side kitting rack

2.4 Time study analysis

In theory, time study analysis was done by observing and measure workers time to do work (task time). Due to Covid19 restriction, the time study at Sweden's model production line could not be performed as admission to the production was restricted. As an alternative, the time required to pick up the plastic components on the new kitting rack was based on the current time required for workers to kit the plastic parts on the Japan's model production line kitting trolley. The time taken was determined by the workers' recorded video, as each level of the slotted space on the kitting rack requires a different amount of time to pick up the plastic component. The Japan model kitting rack was a reference point for the time required to pick up the plastic component because it is identical in shape and height to this new kitting trolley. To determine the new total time spent by workers assembling the rear back seat, the time spent picking up the plastic component from Japan model kitting trolley would be added to the current time spent assembling the seat according to the process book for rear back seat assembly, which does not include time spent picking up the plastic components.

2.5 CAE productivity simulation analysis

Next, a comparison of theoretical assembly time that includes kitting rack and current assembly time was made. This was to verify whether travel and pre-kit time were reduced/eliminate or not. During Covid-19, the company had prohibited actual time study at the RB 40% and RB60% assembly line. Nevertheless, the assembly time for both assemblies in plant was obtained from the company's standard operating process data book [18]. It provides theoretical task time for each task for the Sweden RB40% and RB60% assembly. For time related to kitting rack implementation, the data were taken from Japan RB40% and RB60% assembly line standard operating book. After this, a discrete-event simulation software namely Flexsim was used to simulate the time study of workers assembling the rear RB40% and RB60% respectively.

Implementation of the kitting trolley in the assembly line was simulated in terms of operating time assembling the rear back seat. The arrangement was based on actual assembly layout and location of kitting trolley was based on kitting trolley at Japan's car assembly line. The total working hours of the company was 9.5 hours from 7.40 a.m. to 5.30 p.m., but one hour has been deducted for the employee's break time. The software determined the time required to assemble the back seat based on the current time and the new current time required. Moreover, assembly workers' time spent on kitting tasks would be included to determine the current time taken to assemble one set of car seat. As illustrated in Fig. 5., the simulation analysis for the current layout includes several fixed resources such as input, seat storage, workstation, operator, and output.

The parameter value for each fixed resource were determined using data from the information from the process book and earlier observation (before Covid) at Japan model assembly line. Fig. 6 shows the value and parameter that were set up for the workstation and seat storage resources. For the queue resources (seat storage), the maximum wait time was set to 12 seconds, as this was the time required for the assembly workers to retrieve the seat frame from its storage area. The software's units of measurement were in seconds.

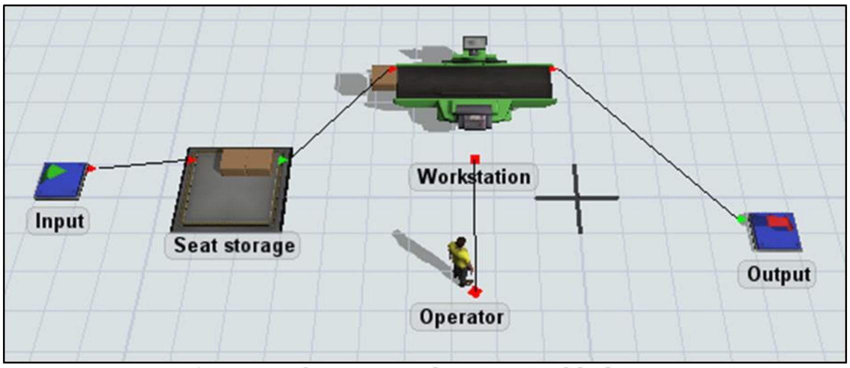


Figure 5. Flexsim simulation assembly layout

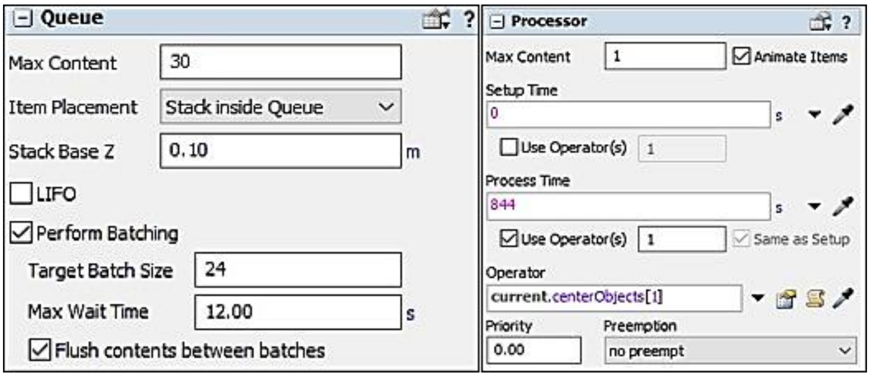


Figure 6. Parameter setup for queue (seat storage) and processor (workstation)

3.0 RESULTS AND DISCUSSION

3.1 Kitting trolley final design and configuration

Fig. 7 and Fig. 8 show the final design and slots configurations for RB40% and RB60%, respectively. For RB40% the dimensions are 1145mm in length, 700mm in depth and height of 1350 mm without the wheels while the dimensions for RB60% are 1500 mm length, 800 mm in depth and 1560 mm in height without wheels.

3.2 Time study simulation

The cycle time without (current practice) and with kitting trolley usage was shown in Table 2. 28 secs and 62 secs of time were reduced with usage of kitting trolley for both seat types of productions. The reduction of time was because traveling time from workstation to the poly-box storage location was eliminated. With implementation of trolley, which is located besides the workstation, workers would not waste time to travel and to perform pre kit prior to assembly process.

Table 2: Cycle time per seat

Seat type	Current total time taken (secs)	New total time taken (secs)
RB 40%	844	816
RB 60%	1435	1373

Next, the productivity was determined by comparing the actual production versus the target production (Table 3). It is seen that RB40% exceed the target production (100% productivity) but not for the RB60% assembly line.

Table 3: Productivity (target: 24 seats a day)

Seat type	Current production	Expected production	Current productivity (%)	Current productivity (%)
RB 40%	36	37	150	154.2
RB 60%	21	22	87.5	91.2

3.3 CAE productivity simulation analysis

3.3.1 Flexsim current time and productivity simulation

The simulation shown in Fig. 9 indicated that 37 sets of car seats could be assembled within the working hours for RB40%. Productivity was found to be increased for RB40% as output is higher compared to target production (54%). The assembly production could be done during normal working hours as the plastic components used, and the tasks performed for RB40% assembly is not as numerous as RB60%. The current time taken in the workstation is 844 seconds, while the seat storage time is 12 seconds, as this is the time required for workers to retrieve the seat frame from the seat storage and bring it to the assembly workstation. The working hours for the current time taken simulation analysis also included the 4.5 minute which is the time required for kitting tasks. The data displayed for the seat generated by the simulation software is largely consistent with factory working hours. Concerning the 40% side, workers have no difficulty meeting their target output of 24 car seats per day.

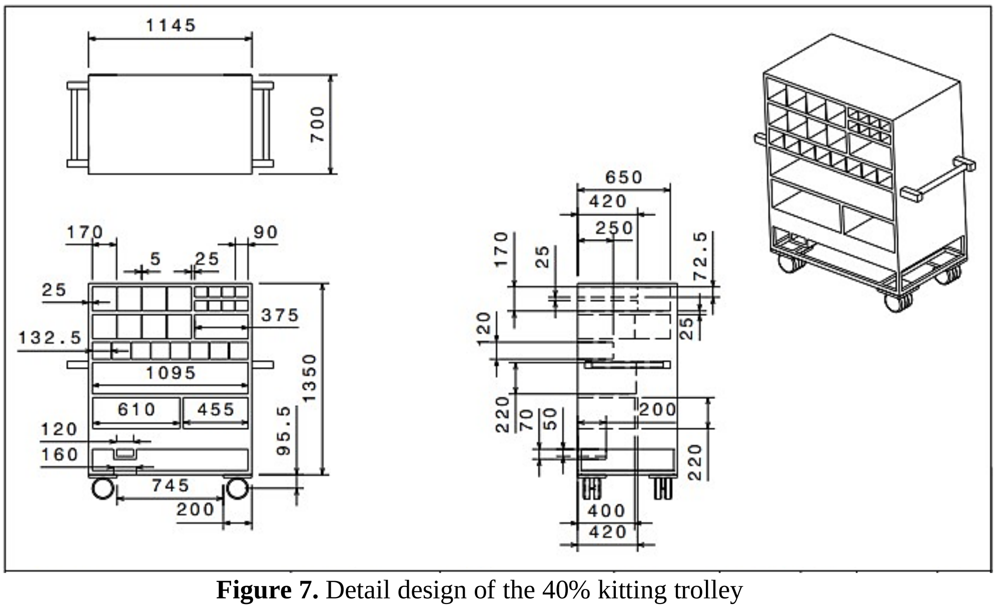


Figure 7. Detail design of the 40% kitting trolley

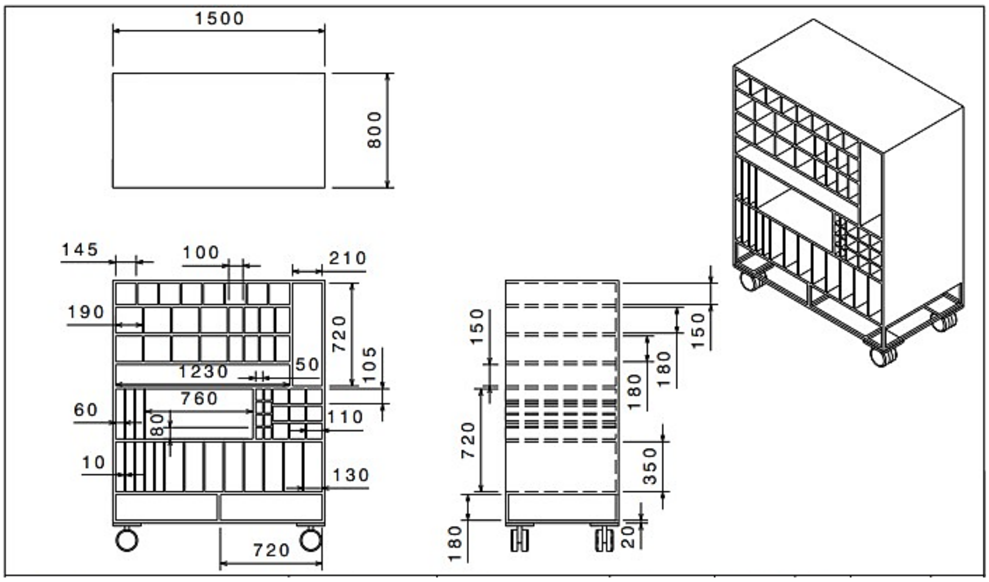


Figure 8. Detail design of the 60% kitting trolley

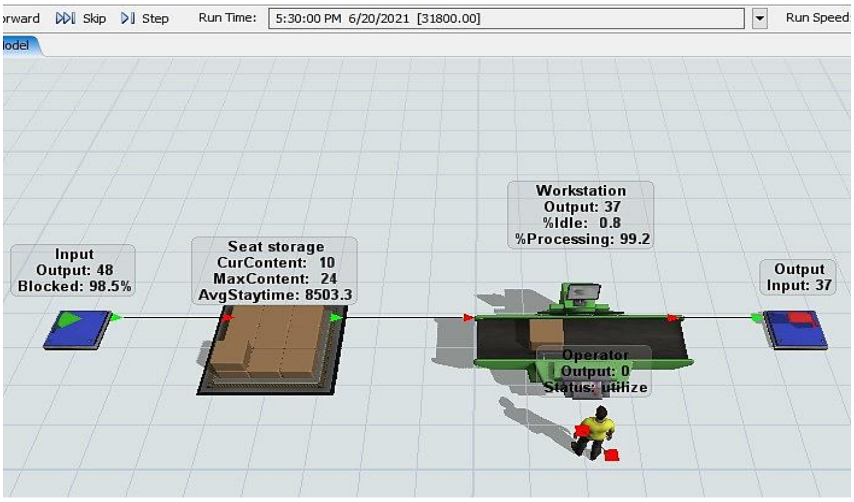


Figure 9. RB40% Flexsim layout and time simulation for current assembly

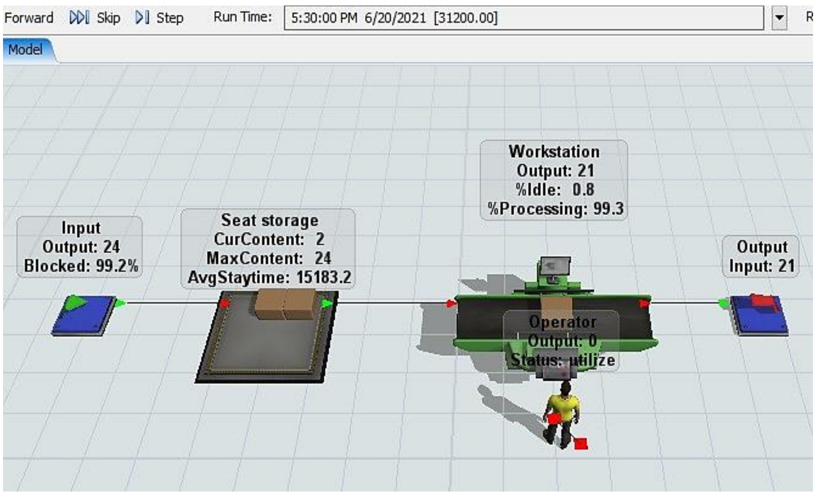


Figure 10. RB60% Flexsim layout and time simulation for current assembly

In contrast to RB40%, the output of RB60% seats assembly (as shown in Fig. 10) was 21 sets of car seats within the working hours which did not achieve the target (24 car seats). The current time spent at the workstation was 1435 seconds, while the seat storage time was 12 seconds, due to the fixed time required to retrieve the frame seat. The reason their targets were not met during the time they worked was due to disruptions such as workers being required to perform kitting tasks which took 10 minutes prior to beginning their assembly work. The 60% sides assembly had more components thus more assembly tasks as compared to 40% sides assemblies. Hence the workers must work from 7.40 a.m. to 6.35 p.m. (an additional 1 hour and 7 minutes overtime) to achieve target.

3.3.2 Flexsim new time and productivity simulation (with kitting trolley usage)

Fig. 11 showed the output for the new time is 38 car seats. As can be seen, there has been a slight improvement since the assembly line's new kitting trolley was implemented. The improvement is possible because the time required for workers to perform kitting tasks is eliminated, as kitting tasks will be performed by warehouse workers. Assembly workers are now only required to perform assembly tasks thus the workstation's parameter setup is 816 seconds, The 40% improvement is still considered acceptable because workers can still produce more than 24 sets of car seats per day. Meanwhile for RB60%, the output of rear back seat assembly is 22 sets of car seats within working hours (Fig. 12) which is still less than their daily target output but is an improvement of one set of car seats over the current analysis. As time for kitting is eliminated, the new time spent at the workstation is 1373 seconds. Although the improvement is minimal, it has the potential to increase the efficiency of working hours.

Based on the improvements shown by the simulation software, the workers' productivity can also be increased because the time required to assemble the car seat can be shortened. As previously stated in various existing studies, the usage of simulation software can be utilized to determine an increase in the productivity of workers performing their duties and tasks. According to [21], the company used the FlexSim software to shorten the duration of industrial processes for a maintenance unit. The expected results of the simulation analysis using the proposed layout indicate that the locomotive's travel time for repairing jobs can be lowered from 280 to 265 minutes and its efficiency increased from 85.71 to 90.71%. Additionally, as described by [16], this study used the FlexSim simulation software to create a simulation model and perform a break-even analysis for painting robot improvements.

The simulation analysis showed that the proposed production is more productive than the current production by 4.38 times, and the worker productivity also increases from 6.52 unit/man/hour to 28.61 unit/man/hour [16]. Moreover, as reported by [22], it employed the FlexSim software to study the Melamine dish manufacturing process to boost both the quantity of goods and the quality of the manufacturing process. The results indicate a 1.385 % increase in production as compared to the existing scenario. Other than that, [7] stated that it used the FlexSim software for modeling and simulation analysis in the company's production of a dowel ring to increase the product's productivity. The simulation analysis predicts that production can be increased to 44.14%.

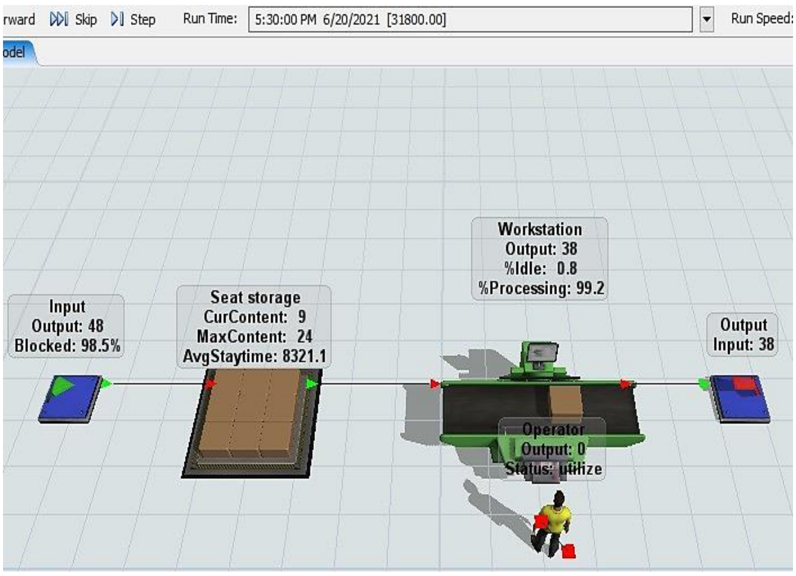


Figure 11. New RB40% Flexsim layout and time simulation for current assembly (kitting trolley implementation)

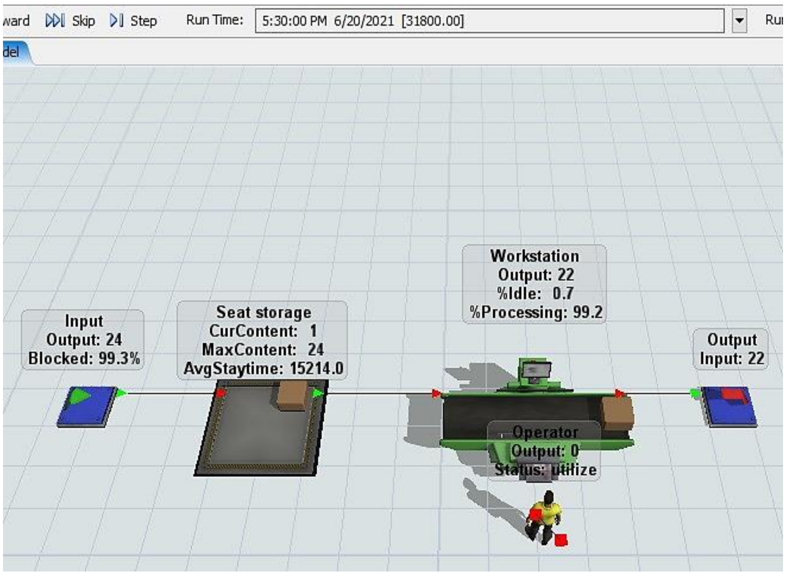


Figure 12. New RB60% Flexsim layout and time simulation for current assembly (kitting trolley implementation)

4.0 CONCLUSION

This study that was based on actual car seat assembly production had managed to design and develop the product architecture and detail drawing of kitting trolley. Kitting trolley would be able to reduce assembly line worker time thus increase in productivity from 150% to 154.2% for RB40% and 87.5 to 91.2% for RB60% respectively. Validation from FlexSim had shown that for RB40% the output was 38 seats (158.3%) while output for RB60% was 22 seats (154.2%) which is similar to time study analysis This finding supports the belief that the new kitting trolley would aid the production line by eliminating inefficient motion, labour, and waiting time associated with product restocking. Nonetheless, bigger increase in productivity for RB60% could be obtained by actual recording on Swedens assembly line rather than relying on the company process book data. Additionally, studies such as project management scheduling can be undertaken for assembly activities unrelated to the movement required to pick up components from the kitting trolley, enabling the removal of redundant chores and the maximum use of personnel for numerous tasks. This may result in additional time savings.

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