Pull-based Operations in a Hostel Mess: A Case Study

M.Manohar, Sreekumar K.P., I. Saran Kumar, Y. Reena, C. SudeepCarey,
Aabir Mohsin and V. Madhusudanan Pillai
Student, Department of Mechanical Engineering
National Institute of Technology Calicut, India
manoharmahapatro@gmail.com, sreekumar_m210066me@nitc.ac.in,
ika_m210541me@nitc.ac.in, reena_m210534me@nitc.ac.in, sudeep_m210539me@nitc.ac.in,
aabir_m210540me@nitc.ac.in,
vmp@nitc.ac.in

Abstract

Wastage is reduced in the manufacturing process by employing a lean manufacturing technique known as the pull production system. In pull production, Kanbans are used to manage production activities. They are a basis for: when an item is to be manufactured, how many are to be produced, etc. In the current operation, food and groceries are carried from one station to another and enhancing it using lean manufacturing principles is addressed in this article. The primary aim is to reduce inventory, eliminate shortages, and reduce system work-in-progress of raw materials, all of which will be accomplished through lean methodologies. A schematic diagram of the pull process is constructed considering the current workstations in the mess kitchen. The number of distinct kanban's necessary is computed. Implementation of lean production system with kanban's dramatically improves the mess's performance. Compared to the existing system, the proposed system would use fewer raw materials (work-in-progress) to meet the same demand. The proposed system will greatly improve the system's efficiency and station cycle times.

Keywords
Lean Manufacturing, Pull Production System, Kanbans, Work-In-Progress and Cycle Time.

1. Introduction
The main goal of lean manufacturing is to increase productivity while decreasing waste and expenses. Important measures towards this goal are to:(i) minimize the inventory levels and cycle time and (ii) increase the utilization of workforce and facilities and pull production is a proved tool for achieving the goal (Puchkova et al.2015).

Conventionally, push production systems are in use for production operations. In push system, production quantity is determined in large lots and is pushed towards the downstream stations. Hence work-in-process (WIP) is usually very high and poor response to demand variations. As a result, a general push system has high inventory holding costs, short inventory turns, a significant risk of product disintegration, and low service levels (Puchkova et al.2016). Thus, many businesses have used a pull approach for production operations throughout the last few decades. The pull-type system directs production in response to client's demand. Instead of pushing items from manufacturing capacity, it allows inventory levels to be constrained and the WIP is managed by kanbans.

The kanban system is one of the strategies used in lean manufacturing to attain minimal inventory at any given time. The kanban method is beneficial in several ways for managing operations and business in a company. It aids in increasing firm's productivity and reduces manufacturing waste. The Kanban method can be used in manufacturing for only when there is a demand for the product (Rabbani et al.2009).

Kanban (kahn-bahn) is a Japanese term that literally translates to "visible component" (Rahman et al. 2013). In general, it refers to some form of signal so it refers to cards in production. The kanban method is based on a client requesting a part from the part's supplier. The client of the part might be a final product consumer (external) or the production staff at the next station in a manufacturing plant (internal). Similarly, in a manufacturing plant, the supplier may be the person at the previous station. Kanban's principle is that material will not be created or moved unless a client signals it to do so. Most firms have created numerous tactics and ways to make their production processes more efficient and effective in order to attain manufacturing excellence. Most Japanese organizations utilize the kanban method because it reduces inventory stock levels and overhead expenses by eliminating overproduction, providing flexible work stations, decreasing waste, lowering waiting times and logistics costs (Rahman et al.2013). As the number of kanbans utilized affects the product inventory level, managers must determine the number of kanbans used during the system's introduction phase. Moreover, the number of kanbans can significantly influence the load balance between processes and the number of orders needed to obtain suppliers from subcontractors.

1.1. Objectives

In this paper, a pull production system is proposed for a hostel mess, which currently employs push system, the observations made from the study are compared with the present existing push production system. The primary objectives of this paper are:

- To divide the mess into a certain number of workstations based on the type of item produced.
- To calculate the number of kanbans required for each item and thus to propose a kanban based cooking operation for the hostel mess

2. Literature Review

Striving to be a low-cost producer in volatile and price-sensitive markets is a powerful competitive advantage. The impact of practices such as Lean, Agile, and Green on the competitiveness of business can be studied with indicators such as cost, lead time, and environmental waste. Push production systems, as mentioned in the introduction, depend upon the forecasts of the demand, and the reliability on these forecasts is quite heavy, information about the stock levels is another such factor, push production is very dependent on the quality of the above mention information and their sources. Pull depends on the supply ability of the system which reduces the WIP through the system.

Many such studies introduce and support the use of production techniques; one of such techniques is employing lean production in an attempt to reduce waste at various stages. The results from a recent study show a variation in the outcomes when the lean, agile and green concepts are applied at different product life cycles (Udokporo et al. 2020). Another recent study employs the lean method – value stream mapping to identify and eliminate waste according to the seven wastes of lean. The changes brought include changes in the layout and material handling methods, which resulted in a reduced lead time of 739 min compared to the original 1102 min, and an increase in production from 33 to 40 units per day (Sirajudeen and Aravind Krishnan 2022).

This section gives review of various literatures around the implementation of pull system and introduces concepts involved in a pull system. Kanbans are one such concept, a simulation-based model - "simulation-based optimal setting (SBOS)" algorithm was used to find the optimal parameters of a pull system. The pull systems discussed include the Kanban, base stock, CONWIP, hybrid and extended kanban. The numerical results show that the extended kanban system performed best among the mentioned system types (Ohno 2011).

MKSD (multi-kanban system for disassembly) is relatively a new approach for controlling the material flow in pull system to minimize the risk factors. When compared with push system in terms of cost, capacity requirements, and time under certain assumptions, MKSD outperformed push system in every aspect (Nakashima and Gupta 2012). Kanban utilization can also aid in increase of the quality and output level of production. The following results were obtained in a medium scale polymer manufacturing industry by the implementation of E-kanban, TMP and Just-in-time production strategy:(i) a 2900min reduction in equipment breakdown time, (ii) productivity improvement by 10% and (iii) increase in OEE by about 25%, which is given by product of availability, performance and quality rate measures of the equipment. All these effects could significantly reduce operational costs (Senthilkumar and Nallusamy 2020). The production environment can greatly affect the kanban system under multi-stage and mixed-model assembly line conditions. The capacity of the kanban system is directly proportional to the probability of stock out and inversely proportional to the WIP (Yang and Zhang 2009).

When different cost and volume combinations are involved in the procuring or production stages, it is beneficial to use a combination of push and pull systems. Control strategies that combine push and pull production approaches are commonly termed Hybrid Push/Pull systems. An initial research into the hybrid pull and push system utilized a modelled structure of production control for multistage manufacturing processes for analysis. For a specific demand model and forecasting model, the behaviour of the inventory levels and production levels are compared (Hirakawa 1996). The ATO (assemble-to-order) environment was also considered to investigate the behaviour of push, pull and hybrid systems in terms of cost and delivery lead-time under different coefficient of variations of demand and cost ratios. The push and pull systems performed better at higher and lower cost ratios, respectively, and the hybrid system performed better in the remaining scenarios (Ghrayeb et al. 2009).

The approaches that impose an upper limit on the overall work-in-progress (WIP) inventory with kanbans are CONWIP (Constant work-in-progress) and pull systems. CONWIP, pull, and push systems were compared in terms of total cost by developing a mathematical model under three scenarios considering undisrupted behavior, resource breakdown, and product quality loss. CONWIP provided better results in terms of cost reduction under the first and second scenarios and for the third scenario, push production excelled (Puchkova et al. 2016). Control systems can be compared under different scenarios and chosen for the requirement. Hybrid push/pull control system and CONWIP/pull control policy under various measures such as Inventory costs, Shortage costs, and Raw material inventory are compared. The comparison shows that a low WIP was obtained when pushing was used at the initial stages, and pulling at the remaining stages. The possibility of using a Hybrid Pull/Push system and how different combinations of using pull and push at various stages of the process affect the objective of the study are discussed in (Gonzalez R 2010). Sharmaand Agrawal (2009) considered a multi-stage production system under different probabilistic demand situations such as binomial, poisson, lognormal, and exponential distributions. CONWIP, kanban, and hybrid policies were considered and AHP (Analytical Hierarchy Process) was used for selection purpose. CONWIP was better for lognormal distribution and Kanban system was better for remaining situations. A job shop environment with demand-pull production control was studied to learn the effect of variability in setup and processing time and the performance measures used were average WIP inventory and average flow time. Three basic shop configurations (i.e., functional layout, cellular layout with backtracking flow, and cellular layout with unidirectional flow) were considered, and the results obtained were qualitatively discussed. Varying features (in this case the layout or the setup time or process time variabilities) can affect the performance measures, and for achieving the required performance, different parameters of the process have to be tweaked (Li 2003).

In a pull system, a stock point (store of inventory at a preceding station of a process) must have the minimum inventory to be withdrawn from the subsequent station. Another system based on inventory is a parts-oriented system that retains the necessary parts prior to the consumption of parts to produce final products. Therefore, the system is based on the parts inventory as in the pull system. Both parts-oriented systems and pull systems have a “variety-production environment”. The inventory cost of both the structures was studied by using the inventory structure. When the variety of products is low with a low safety stock coefficient, pull production gives low costs compared to the parts-oriented system but the advantages of parts oriented system increase when variety increases (Miyazaki 1996).

Apart from significant results in areas of inventory and setup time reduction, pull production when employed can reduce defects produced. Six sigma - lean integrated framework (sustainable lean production framework-SLPF) when applied to a cookware manufacturing company as part of a case study produced a significant improvement; a reduction in machine setup time from 135 min to 15 min and in scrap generation from 127 kg to 4.5 kg and more importantly a reduction in defect rate from 41% to 1%, and a $120,142 saving per year. These results were directly due to the implementation of a lean-based framework which included 15 steps in 5 different stages (Tiwari et al. 2020).

Different methods were introduced by previous researches that consider optimization and learning techniques for WIP reduction. A new technique was studied called Pull-Batch-based Repetitive Scheduling (PBRS) which could reduce cost, time, and WIP compared with conventional repetitive scheduling (CRS). The validation showed that the cost, time, and WIP values are much lower compared with CRS method (Saad et al. 2021). Different methods can be used to determine the arrangement of workstations and number of kanbans in a pull system. A genetic algorithm was used to find the optimum order of allocations of workstations with reduced production cost. A particular arrangement of workstations was obtained and the total cost is reduced by 8% (Lee and Wang 2008). Another use of mathematical advancement was to find optimal order sizes. A memetic algorithm (MA) was applied to a kanban system that controls a multi-stage supply chain to find the optimal conditions for batch size, cost, and number of kanbans and the results were compared with the branch-and-bound method (BBM). In terms of cost, both showed similar results, but in terms of lot size and number of kanbans, MA performs better (Rabbani et al. 2009).

This literature review gives different possibilities to explore the implementation of a lean ideology in a production system. The approaches/discussions on “concepts of kanbans”, “setup time and variability reduction”, “inventory levels”, “workstations” are the important aspects to be considered in the present paper. Further, the literature review considered concepts/models/discussions related to “adaptations of CONWIP”, “Hybrid Push and Pull systems” and “procedures used to study the systems” which are providing direction for a future scope of the present work. At its core, building around the demand of consumer in the efforts of minimizing non-value adding process or time is the basis of a lean pull system. This paper builds on this literature review and proposes a lean production approach based on kanban system for a hostel mess cooking operation.

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3. Data Collection

In this article, a hostel mess which currently works in a traditional way, is taken into consideration. Here, the main objective of this study is to implement a pull production system which is a lean manufacturing system in a conventional mess and to quantify the advantages. To develop a lean production model, the first step is to understand the current system adopted in the mess.

Currently the dining hall is equipped to serve 450 inmates at maximum capacity for 3 times a day and 280 inmates along with 20 staff members are using it. In total, 7 cooks and 13 other employees are working for functioning of the mess. The serving stations that operate in the dining room include a large stove for cooking rice, 3 stoves are designed for cooking Dosa, Chapati and Parotta. A grinding machine for making batter for Dosa, a dough maker for making dough used for poori, parotta, and chapati, a chopping table for cutting vegetables, a table for making raw poori/chapati, and a washing space for cleaning and soaking vegetables. The current layout of the kitchen is shown in Figure 1. Stoves are numbered serially from 1 to 10 according to the actual layout of the mess.

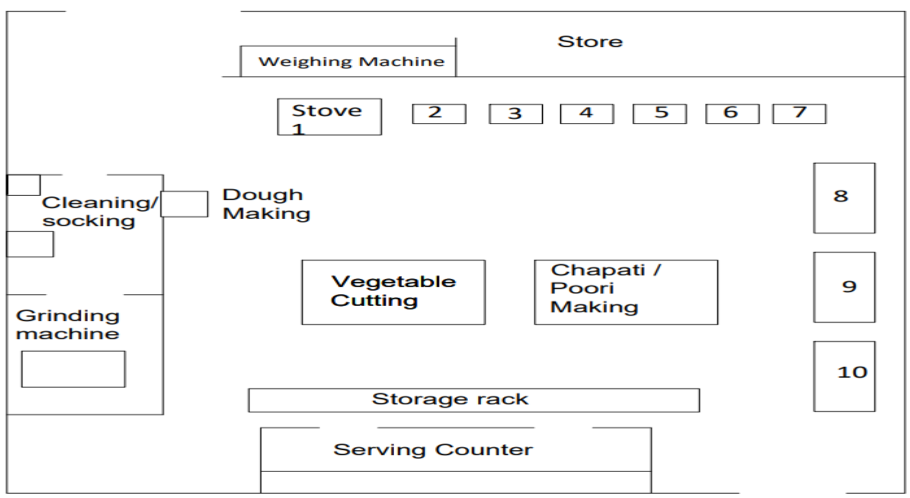

Figure 1. Current kitchen layout

Grocery items are supplied from the central store that operates in campus where delivery is made every Tuesday and Friday. A local store is available near the dining room to store ingredients and vegetables. The food items served and in-progress items required in the mess are listed in Tables 1 and 2 and the required groceries are shown in Table 3. Each food item is given a code in order to identify it easily for further procedure.

Table 1. The food items served in the mess

S. No.	Description	Code
1	Rice	A
2	Idly	B
3	Dosha	C
4	Chapati	D
5	Poori	E
6	Sambar	F

7	Dal	G
8	Dry Veg curry	H
9	Gravy / Curry	I
10	Veg Biriyani	J

Table 2. In-progress items required

S. No.	Description	Code
1	Dough for Chapati / Poori	K
2	Batter for Idly/ Dosha	L
3	Raw Chapati / Raw Poori	M
4	Grounded masala	N
5	Chopped vegetable	O

Table 3. Grocery items supplied from the central store

S. No.	Description	Code
1	Rice	P
2	Raw Dal	Q
3	Spices	R
4	Ghee	S
5	Pulses	T
6	Atta	U
7	Cooking Oil	V
8	Vegetables	W

4. Methodology

While proposing a new method for preparing the food items, it is also important to know the in-progress items required for preparing the main items, and the groceries and vegetables required for the preparation of in-progress items. Hence, a single level bill of material (BOM) is developed for clear understanding the preparation requirements which is given in Figure 2. Here, P, Q, R, S, T, U, V, and W are the raw materials obtainedfrom the central store.

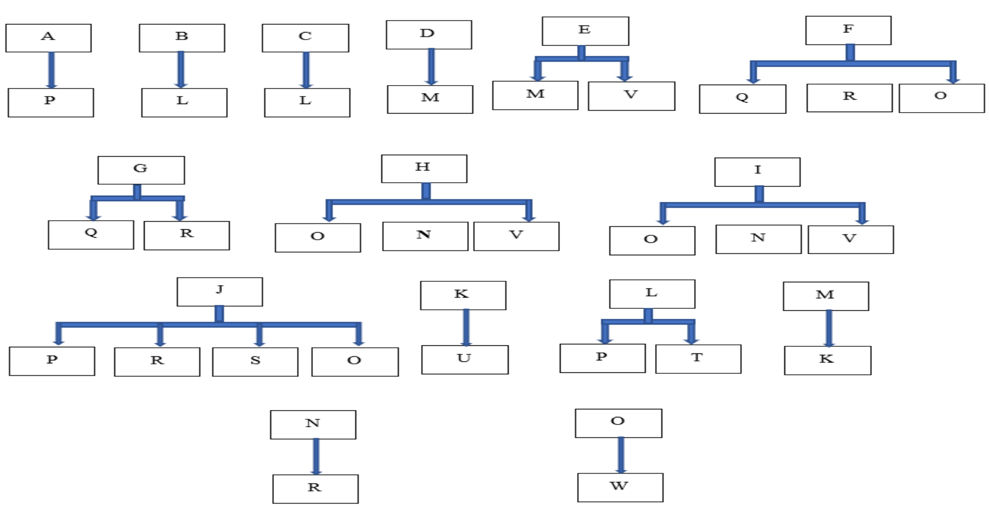

Figure 2. Single level BOM for each item

For this study, a field survey is conducted about working of the mess. Based on the interaction with the mess staff, a tabulation is formulated about the ingredients which is given in Table 4. It describes the lot size required for each item and in-progress items along with activity time and waiting time.

Table 4. Activity time and Waiting time description for each item

S. No	Description	Code	Lot size	Activity Time in minutes	Waiting/ Pre-processing Time in minutes
1	Rice	A	1 lot	60	25
2	Idly	B	90 No	18	20
3	Dosa	C	25 No	5	18
4	Chapati	D	25 No	5	18
5	Poori	E	12 No	4	21
6	Sambar	F	1 lot	80	48
7	Dal	G	1 lot	80	48
8	Dry Veg Curry	H	1 lot	56	30
9	Gravy / Curry	I	1 lot	60	32
10	Veg Biriyani	J	1 lot	90	25
11	Dough for Chapati / Poori	K	2 lot	18	5
10	Batter for Idly/ Dosa	L	2 lot	45	200
11	Raw Chapati /Poori	M	4 Lot	5	15
12	Grounded masala	N	1 lot	10	12
13	Chopped vegetable	O	1 lot	50	30

After going through the collected information, it is found that there is no proper procedure for planning of flow of grocery/vegetable towards the kitchen. It is also observed that on average there is a wastage of 10 to 12% of vegetables. Similarly, 6 to 7% of grocery waste is also observed. Due to lack of proper forecast and underutilization of man-power, a wastage of in-progress and finished food items are also noticed. By implementing a systematic procedure, this wastage can be reduced to an optimal level. For achieving the same, lean production system is introduced. The proposed system divides the lot size of the items into sub-quantities, called containers. Container sizes are calculated based on thumb rule (10 % of total demand).

To calculate the size of the container, it is assumed that on average 300 inmates eat food from the mess. Waiting/Conveyance time (C) and Production time (I) required for each operation is listed below as the lead time (LT), and calculated the Container-size (Q) of all items.
Sample Calculation of container size:
For rice (A), idly (B) is given below
D=300 hostel inmates per day per meal
Considering one serving as 150 gm of rice as average consumption, 450 servings are required for 300 inmates. Here, servings mean quantity of the item required for an instance.
Hence, container size = 45
Idly (B)= 900 idly, Q = 10% of 900 = 90
The daily requirement of each meal along with its container size and lead time are given in Table 5.

Table 5. Daily requirement and container size of each item

S. No	Description	Code	Lot size	Daily requirement per meal time	Container Size (10%)	Operation time
1	Rice	A	1 lot	450 Servings	45	85
2	Idly	B	90 No	900 No	90 No	38
3	Dosha	C	25 No	900 No	96 No	23
4	Chapati	D	25 No	900 No	96 No	23

5	Poori	E	12 No	1200 No	120 No	25
6	Sambar	F	1 lot	300 Servings	30	128
7	Dal	G	1 lot	300 Servings	30	128
8	Dry Veg Curry	H	1 lot	300 Servings	30	96
9	Gravy / Curry	I	1 lot	300 Servings	30	30
10	Veg Biriyani	J	1 lot	300 Servings	30	64
11	Dough for Chapati / Poori	K	2 lot	29 kg	2.9 kg	23
12	Batter for Idly/ Dosha	L	2 lot	75 L	7.5 L	225
13	Raw Chapati /Poori	M	4 Lot	900 No	90 No	30
14	Grounded masala	N	1 lot	1 Kg		8
15	Chopped vegetable	0	1 lot	5 Kg		22

To improve mess performance, a kanban system is developed, which is a lean production technique used for managing and tracking of a job moving through a process. To implement the kanban system, workstations are proposed according to the similarity of cooking method while considering the process time of each item. For this, the workstations are numbered and arranged in an order based on the distance between the workstations, i.e., the workstations that are the shortest distance apart are kept in one place and the ones that are the furthest distance are kept on the other to reduce waiting time. Table 6 shows the numbering given and respective product associated for each workstation.

Table 6. Numbering given and respective product associated for each workstation.

Work station No.	Description	Stove / Work table attached	Product associated with	No of cooks/ Helper
0	Super Market	Store	For storing all materials	
1	Cleaning/ soaking Station	Washing Station		2 Helpers
2	Grinding	Grinding M/c	L, N	1 Helper
3	Dough Making	Dough Making M/c	K	
4	Vegetable Cutting	Work table 1	O	2 helpers
5	Raw Chapati / Poori Making	Work table 2	M	2 Helpers
6	Rice / Idly	Stove 1, 2	A, B	1 Cook
7	Dry Veg curry / Dal / Gravy / Curry / Sambar / Veg Biriyani	Stove 3, 4, 5, 6, 7	F, G, H, I, J	2 Cook
8	Chapati / Dosa / Poori	Stove 8, 9, 10	C, D, E	2 Cook
9	Final Counter	Delivery Station		2 Helpers

Figure 3 shows the proposed lean production layout buffer for different items and the arrangement of the different workstations. The circles with number are the operation stations. The number represents the workstation number given in Table 6. This layout consists of different types of kanbans such as S, C, and P kanbans. S-kanban is initiated on a weekly basis according to the forecast based on the number of inmates. Grocery supply is twice a week and vegetable supply is on daily basis. The items received are stored in a super market in the mess. The C-kanbans are used to authorize the transfer of items to respective workstation from the super market. P-Kanban is used to authorize the production at each work station based on authorization of food serving counter.

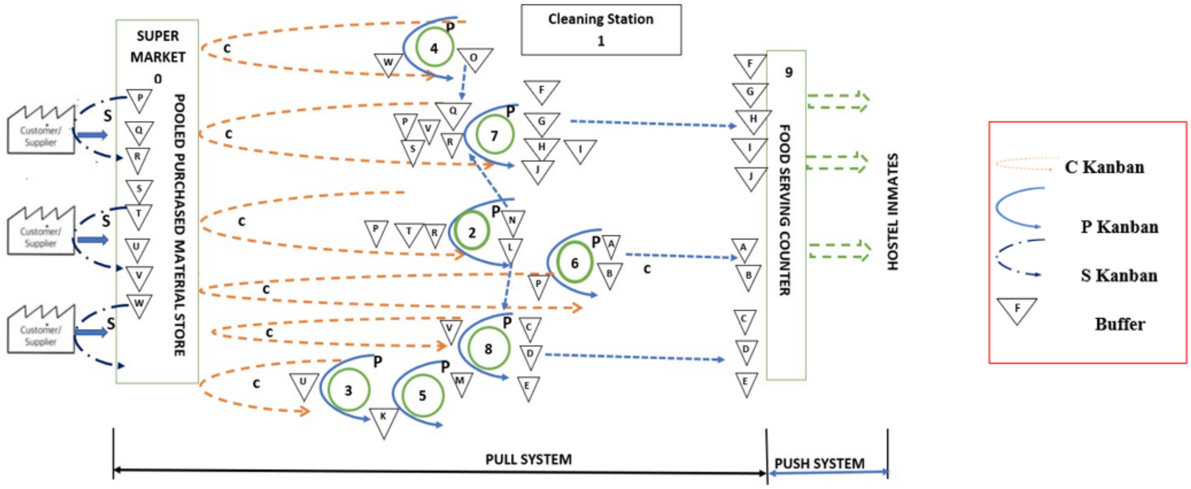

Figure 3. Proposed Lean Production layout with buffers

5. Results and Discussion

The reorder point is expressed in terms of a number of containers, K. It represents the maximum number of completely full containers in a buffer. The pull system often uses cards (KANBANS) and in that case K refers to the number of cards. As soon as one unit is withdrawn from one of these containers, an order for replenishment is sent to the upstream. The number of kanbans required for each item are listed in Table 7.

$$K = \frac{D(P + C)}{Q} = \frac{D\ (LT)}{Q}$$

Here K = Number of containers, D = demand, P = Production time, C = Conveyance time, Q = Container size in units (10% of item demand), LT = lead-time

C-kanbans are required for material transfer between supermarket and some workstations. As all the workstations are close to each other, the conveyance time is considered negligible for final items. Therefore, no C-kanbans are required for final items and only P-kanbans are calculated. The details required for the estimation of number of P-kanbans are provided in Table 7.

Sample Calculation for P-Kanban:

Item F, its demand = 300 units; Buffer location is outbound area of station 7.

$K_{PF} = (D \times LT)/Q$ = (300×128) / (30×180) = 7.11≈8 kanbans

But for items like rice, sambar, dal, and batter are prepared at once hence the number of kanbans for these items are limited to 1.

The average WIP at the outbound area of station 7 is:

Work-In-progress Inventory (WIP) due to item F = 1 container = 1×30 = 30 units

Item D, its demand = 900 units; Buffer location is outbound area of station 8.

$K_{PD} = (D \times LT)/Q$ = (900×23)/90×180 = 2 containers

Average WIP at outbound area of station 8 is:

WIP due to item D = 2 containers = 2×90 = 180 units

Table 7. Number of kanbans required for each workstation

S. No	Description	Code	Daily requirement per meal time	Container Size (10%)	Lead time (min)	Number of P-Kanbans	WIP (units) at outbound
1	Rice	A	450 Servings	45	85	1 (6)	45
2	Idly	B	900 No	90	38	1 (6)	90
3	Dosa	C	900 No	90	23	2 (8)	180
4	Chapati	D	900 No	90	23	2 (8)	180

5	Poori	E	1200 No	120	25	2 (8)	240
6	Sambar	F	300 Servings	30	128	1 (7)	30
7	Dal	G	300 Servings	30	128	1 (7)	30
8	Dry Veg Curry	H	300 Servings	30	96	1 (7)	30
9	Gravy / Curry	I	300 Servings	30	30	1 (7)	30
10	Veg Biriyani	J	300 Servings	30	64	1 (7)	30
11	Dough for Chapati / Poori	K	29 kg	2.9	23	2 (3)	5.8
12	Batter for Idly/ Dosha	L	75 L	7.5	225	1 (1)	7.5
13	Raw Chapati /Poori	M	900 No	90	8	1 (5)	90
14	Grounded masala	N	1 Kg	0.1	8	1 (2)	0.1
15	Chopped vegetable	0	5 Kg	0.5	45	1 (4)	0.5

The raw material has to be moved from supermarket (pooled raw material store) to various workstations (See Figure 3). C-kanbans are used for controlling the material at input buffer area of the workstations 2, 3, 4, 5, 6, 7 and 8. For the calculation of number of C-kanbans, one pieces of data required is conveyance time. A sample calculation of number of C-kanbans for the item P is given below.
Item P, its demand = 30; Buffer location is inbound area of station 6.
Conveyance time from supermarket to workstation 6 is 15 minutes.
K_{CF}=$(D\times C)/Q$ = (30×15) / (3×180) = 0.833 ≈ 1 Kanban
WIP due to item P = 1 containers = 1×3 = 3 Kgs
It is noted that number of C-kanbans for the buffers of various workstation 2, 3, 4, 5, 6, 7 and 8 shown in Figure 3 is obtained as one.
By introducing a kanban-based lean production system, WIP is limited to at most two containers at each stage. Currently, in the dining room, food is produced in large quantity according to the forecast. If there is a change in forecast demand, the WIP loss is quite high. By implementing Kanban-based production, WIP's cumulative inventory is limited to one container size. This leads to savings of food items in process as well as finished items. Similarly, the current procurement system is changed from forecast weekly demand to S-kanban, which also leads to minimizing inventory of vegetables and groceries.

The rearrangement of the work stations is carried out considering the nature of the food, its preparation sequence, the elements used, etc., which leads to a reduction in cycle time and the number of workers employed. Here it can also be noted that the time required to produce Dosa and Chapati can be greatly reduced by employing adequate manpower at the workstation. The kanban system is very helpful in gaining customer satisfaction by serving freshly cooked food compared to the current scenario.
Cycle time estimation:
Cycle time is the time between when units are completed in a process. It gives an idea of piece-by-piece product flow and hence it is important in pull production because it implies repetitiveness and a smooth and steady flow of material throughout a process. Required cycle time is the production target of a process or operation, this is sometimes referred to as takt time, i.e.,

$$CT_r = \frac{Time\ available}{Demand} = \frac{180\times60}{300} = 36 \text{ sec}$$

The total processing time for 300 meals is 180 minutes. So, the Required Cycle time of the system is 36 Seconds. Actual cycle time is the actual production capability of a process or operation. Establishing and standardizing work in a process such that the actual cycle time is as close as possible to the required cycle time is an important concept in a lean production. The actual cycle time is calculated for each worker after application of kanban system and is listed in Table 8.

Actual cycle time $CT_a = \sum Operation\ time + \sum Walk\ time$

Table 8. Actual Cycle Time for each worker

Worker	Sub-cell /Workstation	Operation Time (min.)	Walking Done between stations	Walk Time (min.)	Actual Cycle Time (Sec/Unit)
1	1	25	0 and 1	5	6
2	1	25	0 and 1	5	6
3	2	35	0 and 2	3	7.6
4	4	45		0	9
5	4	45		0	9
6	5	80		0	16
7	5	80		0	16
8	6	85		0	17
9	7	128		0	25.6
10	7	96		0	19.2
11	8	110	5 and 8	5	23
12	8	110	5 and 8	5	23
13	9	60	6,7,8 and 9	15	15
14	9	60	6,7,8 and 9	15	15

The actual cycle time is calculated in terms of seconds per unit in the table above. Here, only the workstations 1 and 2 have walking time because the materials need to be brought from the supermarket to the respective workstations. From workstation 5, items must be brought in on foot for processing at workstation 8. Finished goods are brought to the final counter on foot. All other workstations are close to each other; therefore, the walking time will be very small and can be neglected. From Table 8, it can be seen that none of the worker cycle time is more than the system cycle time.

Efficiency estimation:

Maximum possible efficiency, $e_{max} = \frac{\sum_{i=1}^{j} t_i}{N \times C} = \frac{207.4}{6 \times 36} = 0.96$

Where t_i= i^{th} worker operation time per unit, N = Theoretical minimum number of stations

$N = \frac{\sum_{i=1}^{j} t_i}{C} = \frac{207.4}{36} = 5.761 \approx 6$, C = Required cycle time.

Actual possible efficiency, $e = \frac{\sum_{i=1}^{j} t_i}{m \times C} = \frac{207.4}{8 \times 36} = 0.72$ where, m = Actual number of stations.

6. Conclusions

By implementing the Lean Pull system in the dining room, the continuous consumption of inventory between stations can be reduced, the kitchen staff is assigned to different work stations according to the nature of the food cooked and the time needed to cook. Stations 6, 7 and 8 were in charge of the cooks Therefore, it is difficult to reduce the cooking time. Helpers can be removed to balance the system, and one helper is removed from each of stations 1, 4, and 9. Since the combined cycle time of both workers at stations 1, 4, and 9 is 12, 18, and 30 seconds respectively. Also, this time is less than the system cycle time of 36 seconds. Therefore, one helper can be removed from each of these stations.

The total number of workers in the mess were 20, comprising of 7 cooks and 13 helpers. But the proposed system requires only 5 cooks and 13 helpers with further looking upon cycle time of workers 3 more helpers can be removed from the station. Finally, the mess can be run by 11 workers (5 cooks and 6 helpers) only instead of proposed 20 workers.

Theoretically the maximum possible efficiency is 96% with 6 workstations. But the actual possible efficiency of the system is 72% achieved with 8 workstations. Items produced at each meal are level production as they are produced daily on demand. The dining room service level will significantly improve if the proposed system is implemented. It is possible to achieve zero stockouts or disgruntled inmates compared to the previous system. In the current system occasionally, final items or raw materials unavailability happens. The lead time for each food preparation activity is increased by scenically rearranging the workstation and reducing the waiting time of in process units.

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Biographies

M. Manohar earned his bachelor's degree in Mechanical Engineering from Raghu Engineering College, Visakhapatnam in 2020 and is currently pursuing his final year of post-graduation in Industrial Engineering and Management at National Institute of Technology Calicut. He published two research articles in two different journals as a co-author.

Sreekumar KP is currently pursuing his final year of post-graduation under AICT-QIP Poly Scheme in Industrial Engineering and Management from National Institute of Technology Calicut. Currently working as lecturer in Mechanical Engineering at NSS Polytechnic College. Pandalam, Kerala. Earned his graduation in Mechanical Engineering from TKM College of Engineering, Kollam in 2016.He is a life member of IEI.

I. Saran Kumar is currently pursuing his final year of Master's degree in Industrial Engineering and Management from National Institute of Technology Calicut. He earned his graduation in Mechanical Engineering from RGUKT RKValley in 2020.

Y. Reena is currently studying for her Master's degree in Industrial Engineering and Management from National Institute of Technology Calicut and has graduated with a bachelor's degree in Mechanical Engineering from JNTUH-CEH in 2020.

C. Sudeep Carey is currently pursuing his final year of post-graduation in Industrial Engineering and Management from National Institute of Technology Calicut and has completed his bachelor's in Mechanical Engineering from Sardar Vallabhbhai National Institute of Technology, Surat in 2021.

Aabir Mohsin is currently pursuing his final year of post-graduation in Industrial Engineering and Management from National Institute of Technology Calicut. Earned his graduation in Mechanical Engineering from Jss academy of technical education in 2018.

V. Madhusudanan Pillai, Professor, Department of Mechanical Engineering, National Institute of Technology Calicut, Kerala, India. With more than 30 years of teaching experience and over 150 publications in international journals and conferences, and editorship of a book, he has developed several laboratory exercises and software packages in the area of manufacturing management and supply chain management. His research interest includes modelling of problems in supply chain operation simulation, e-learning tools for supply chain operation simulation, sustainable supply chain management, cellular manufacturing systems, material requirements planning, scheduling, facility layout planning, inventory control, lean manufacturing, manpower planning – annualised hours, ergonomics and machine learning and blockchain applications in operations management. He supervised 10 Ph.D. theses, over 100 Master students and he is currently advising four Ph.D. scholars and three Master students on their research.