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MÜHENDİSLİK FAKÜLTESİ
FACULTY OF ENGINEERING
ENDÜSTRİ MÜHENDİSLİĞİ BÖLÜMÜ
DEPARTMENT OF INDUSTRIAL ENGINEERING

IE-333 Term Project

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A Work Systems Analysis and Design Application at Şok Market

"Academic integrity is expected of all students of METU at all times, whether in the presence or absence of members of the faculty. Understanding this, we declare that we shall not give, use, or receive unauthorized aid in this project."

Group 2

Student ID Number	*Full Name*	*Signature*
2444321	Deniz Arık	
2444693	Emek Irmak	
2517944	Mesut Emre Kara	
2445013	Ömer Turan Şahinaslan	
2445120	Özgür Ünverdi	
2487494	Youssef Nsouli	

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Introduction

This paper will discuss a certain organization's problem and ways to approach and tackle the problem head-on. The organization is a branch of one of the most famous national grocery stores, *ŞOK Market*, that sells products used daily or occasionally. These include dairy and meat products, produce and canned food, snacks, beverages, and deli products, and hygiene products, and more. As such, demand can be high and variable, due to the essentiality of these products to many people, especially the students who reside within the METU Campus.

The main workers of this facility include the cashiers and warehouse workers. The warehouse workers make sure that inventory is stocked and up to date, as well as making sure none of the perishable products have passed their expiration date, and the cashiers serve the incoming customers by scanning the products and processing their payments. The largest underlying issue currently at the chosen organization is of a queueing nature; the queues at the payment point get too long and it takes a lot of time for customers to check-out.

This has caused many customers to get irritated by the long waiting times and get unsatisfied by the service. Potential customers may not even want to try entering the market, for example, a student returning to their dormitory after finishing lectures may skip passing by the market – which is on their way – and may prefer to order groceries online.

Problem

The causes that lead to these waiting times are numerous, but the most influential factors have been pinpointed down after observing the processes in the market and discussing them with the market personnel. One of the causes is that there are too few workers working simultaneously, so too few cashiers are working at one time. Despite there being three cash registers, only two cashiers are available, which keeps one complete cash register idle and not in use. Another cause is that two of the three cash registers are visually blocked by item shelves (as seen in Appendix A) when coming through from the most used lane. More causes include the fact that credit and debit card payments take a lot of time to go through, due to there being an internet problem, as described by the workers. In addition, conveyor belts do not work, so cashiers must manually reach and grab items that are far away. All these factors contribute to a very long queue and waiting times.

Average Waiting Time

To place a number on the number of customers waiting at one single time, a time analysis was made. Two time-elements have been observed:

- Time between customer arrivals
- Service (cash out) time per customer

Data was collected in two sessions: at 11:30 (not crowded) and at 17:00 (peak time). Referring to Appendix B, the average arrival time is 71.19 secs/customer and 40.35 secs/customer in the relaxed and crowded portions of the day, respectively. The respective arrival *rates* are $\lambda_{nc} = \frac{3600}{71.19} = 50.57$ and $\lambda_c = 89.22$ customers per hour, for non-crowded and crowded portions of the day, respectively.

The average service time per customer per cash register is 58.05, as also seen in the observation sheet in appendix B. The respective service rate for each case (crowded or otherwise) requires a few assumptions. During off-peak hours, usually only one of the two cashiers were manning a cash registry, and the other was filing inventory. So, the corresponding service rate is just the reciprocal: $\mu_{nc} = \frac{3600}{58.05} = 62$ customers per hour. During peak hours, one cash registry was working at full pace, whilst the other was idle $\sim 60\%$ of the time (due to queue length inequality). The corresponding service rate is then *assumed* to be:

$\mu_c = (1 + 0.6)\frac{3600}{58.05} = 1.6\mu_{nc} = 99$ customers per hour

The expected number of customers at a single point in time is as follows:

- $L_{nc} \approx 4.5$ customers
- $L_c \approx 9$ customers

The expected waiting time can, then be determined using Little's Laws:

- $W_{nc} \approx 5.4$ minutes

- $W_c \approx 6$ minutes

The calculations of the above figures can be referred to from Appendix C.

The figures are too high to sustain customer satisfaction in the long run. As such, solutions are needed, and alternatives are to be proposed.

Proposed Alternatives

There are three alternatives which have the potential to solve the problem:

1. Hiring a new cashier
2. Making the layout more efficient to reduce customer waiting time by making cash registers nearer to one another.
3. Purchasing an automated cash register to provide some flexibility in purchasing transactions.

Comparing the Alternatives

To overcome the customer satisfaction problem of ŞOK Market occurring due to increasing waiting time in the queue to pay for the products people buy and leave the market, each of the three alternatives utilizes a different approach. Namely one alternative is an investment in labor, another could be a change in layout, and the last is an investment made in physical capital. The word "physical" is used in front of capital to distinguish it from the financial investment made.

Upon discussing with the workers and directors and observing the queue during rush hours, hiring a cashier seems to be an efficient solution to the problem at hand. One of the cashiers in ŞOK has claimed that there are only seven workers in total working for ŞOK, and only six of them can be available in a single working day, considering that every day one of them is on leave. In addition, only four workers are available at one single time. Also, since there are many different jobs and tasks to accomplish in the market, such as inventory management, filling the shelves, customer service, etc., only two workers are available to work as cashiers. However, there are three cash registers that can be used in ŞOK, leaving one idle all the time. So, hiring a worker to ease the queuing lines during rush hour would potentially significantly reduce the waiting time.

After discussing with one of the cashiers, the western part of the cash registry layout could prove more efficient. There are several reasons for that, one being that the western registers are not visible when the customer is waiting in the queue for the eastern register because of a big construction beam obstructing vision. Since the products placed on the eastern side of the market coming before the eastern register are junk foods and staple foods, such as pasta and rice that are very popular among university students, most customers join the queue to check out from that area, creating an imbalance between the queue lines. Also, since the checkout points are far from each other, even if a customer sees that the other register has a shorter queue, they would not want to switch. Hence, as a second alternative, decreasing the spaces between the cash registers can ease the problem.

Finally, self-checkout machines can be used to check out. This machine is in use in other supermarkets, such as Migros, and is known to be time-efficient, if customers are capable of using it. Since most of the customers of ŞOK are METU students who are computer and technology literate, this method has a high affinity to succeed.

Advantages and Disadvantages of Alternatives

The first alternative is much easier to implement than others because there is a high demand for jobs, and its effects can be observed almost immediately. However, it is the most expensive alternative. The present worth of the cost is higher than others (in absolute value), even if its first cost is negligible.

The second alternative entails downtime of the cash registries and the cost of rewiring, decoupling, and moving around heavy machines. Also, it is harder to implement than others since it requires major changes in layout. However, it is the cheapest alternative of the three.

The third alternative is much more innovative than the others and increases the brand equity of the market and has the most potential to decrease waiting time. On the other hand, the market management may dislike this approach, considering that the first cost is too high, and disregard it.

Efficacy of each Alternative

To determine the efficacy of each alternative, optimally, the alternatives would have been implemented and observed. However, this was not an option, so determining the efficacy will be done according to assumptions and presumptions. For these purposes, the rush-hour figures will be used since it is more critical.

Hiring another cashier, which is the first alternative, entails the assumption that the western cash registers will not work at maximum pace, due to the aforementioned problem where customers do not see these registries. So, it can be safely assumed that two of the three registers will operate at 60% efficiency, each. Now, since there are three cash registers and as many employees to man these registers, the expected number of customers would drop roughly to 1.85 customers (calculated using the same equations in appendix C, while assuming $\rho = \frac{\lambda_c}{2.2\mu_{nc}}$). Thus, there is no queue expected with this alternative applied.

The second alternative is related to changing the layout, making both cashiers equally visible. The decrease in the number of customers in the queue/store is hard to estimate as it is difficult to pinpoint what portion of the customers don't see the other checkout. Although, at best, both cash registers would work at the same pace, decreasing the expected number of waiting people to roughly 2.56 customers, less than hiring another cashier. As for the worst case, the expected number of customers remains the same; however, the cost of implementing this alternative is the lowest as well, giving it an edge over the other alternatives.

The self-checkout option is the easiest to estimate, since there have been studies around the subject. According to the article by Andrews (2019), thanks to self-checkouts, average queue time in retailers can be reduced up to 40%. In addition, a study conducted by Kokkinou and Cranage (2013) also points out that self-checkouts have a significant impact on total waiting time. In the study, they experimented on a hotel check-in system, installing one self-checkout machine in addition to two existing employees – which is mildly similar to ŞOK's case – and the arrival rates are also somehow comparable. Kokkinou and Cranage's experiment resulted in decreasing average waiting time to 10% of the original value.

According to Kiosk Manufacturer Association (2022), 48.7% of customers prefer the self-checkout option. Keeping this in mind, considering that generally middle-aged and young people visit ŞOK in METU Çarşı, the average percentage customers that may prefer self-checkout is roughly 50%. The expected number of customers that would wait in line would drop to 0.8 customers (when considering that arrival rate will be cut in half). This alternative has proved to be the best in terms of decreasing waiting times.

Solution

After several assumptions and calculations, and after all factors were taken into account, the best option seems to be to offer customers self-checkout points. The reason changing the layout alternative was eliminated is that, along with the repositioning cost, it would cause the system to stop for a such long time and even though the improvement it will cause is neither certain nor more radical than the other alternatives.

If the business brings in one more cashier rather than an automatic checkout system, there will be certain improvements in customer waiting time; however, since the layout of the market is problematic, a newly proposed optimal layout might not bring about many improvements. Adding a new cashier will most likely result in one-fourths of the customer waiting time; however, the respective cost is a running cost and will build up over time instead of a big, one-time payment.

Self-checkout systems, on the other hand, can be bought at a price between 10,000₺ and 90,000₺, depending on the features that come along with it. Maintenance and hardware or software breakdown costs are assumed to be about 10% of the initial cost. Considering that an average self-checkout system is sufficient, its cost would be about 50,000₺ and 5,000₺ for the maintenance. Since the cost alternative is employing a cashier with minimum wage, 8500₺, both alternatives can be compared using cash flows table and present worth analysis. According to regulations, the lifetime of self-checkout system is assumed to be 5 years (Presidency of The Republic of Türkiye Legislation Information System, 2020). Hence, the cash flows table for both alternatives are drawn in terms of 5 years of time horizon as in Figure 1.

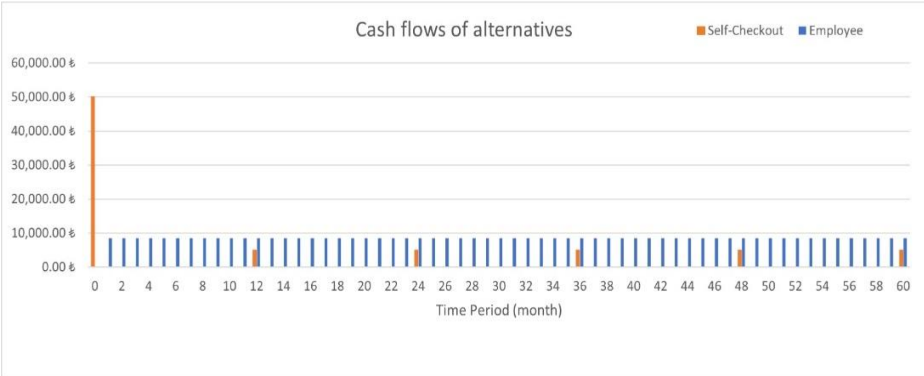

Figure 1: Cash Flows of Self-Checkout (including maintenance and upkeep) and New Employee Wages.

In order to assess the alternatives, the cash flows are converted to their present values using present worth analysis, as in appendix D. For the purpose of these calculations, yearly interest rate is taken as 20% considering approximate market interest rates of banks, and monthly interest rate is calculated accordingly. In addition, the cumulative present worth along operating time can be seen in Figure 2, which demonstrates that the self-checkout alternative is far cheaper than employing a new cashier, making it a much more preferable option.

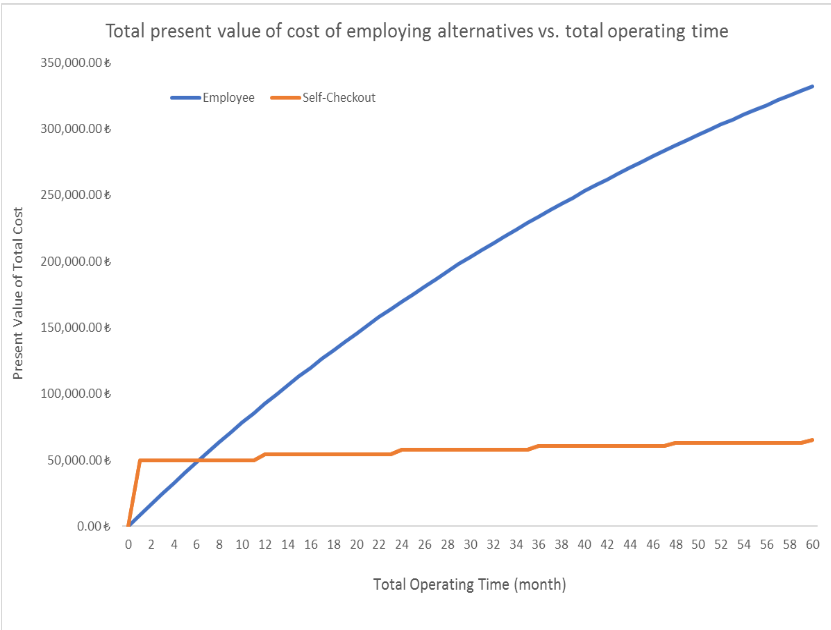

Figure 2: Cumulative Present Worth of Self-Checkout Machines Vs. a New Employee.

Conclusion

The three alternatives in consideration were hiring a new cashier, changing the layout of one of the checkout points, and opening self-checkout points. The first option, hiring a new cashier, could increase the ease of customer circulation and decrease the queue time at other checkout points. It simply multiplies the service time by two-thirds and saves a great amount of time. However, it also means a new wage cost for ŞOK which cannot be underestimated.

The second option, changing the layout of one of the checkout points, could balance the preference ratios of customers by getting more attention than before and decreasing the intensity on the other checkout point. However, it would cause a long out-of-service time for the checkout point, focusing all the workload on the other checkout point. Besides, the relocation process might take a few days in the store, which affects customer satisfaction adversely.

The third option, installing self-checkout points, is innovative and uses the practicality of technology to decrease queue times and wage costs for cashiers. However, it means new capital investment for ŞOK and in the beginning, might be hard for both the customers and cashiers to get used to.

All in all, the self-checkout system is the most advantageous alternative because of following reasons:

- It only requires capital and maintenance annually, which is more cost-efficient than other alternatives.
- It decreases queue time radically, in the order of one-fourth.
- It makes the layout more efficient since it does not require much space compared to the traditional checkout system.
- It increases customer satisfaction by letting them checkout more quickly and easily.
- The usage of high technology product increases the company reputation from the customers' perspective.

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Kokkinou A., Cranage D. A. (2013). Using self-service technology to reduce customer waiting times. *International Journal of Hospitality Management, 33,* 435-445. https://doi.org/10.1016/j.ijhm.2012.11.003.

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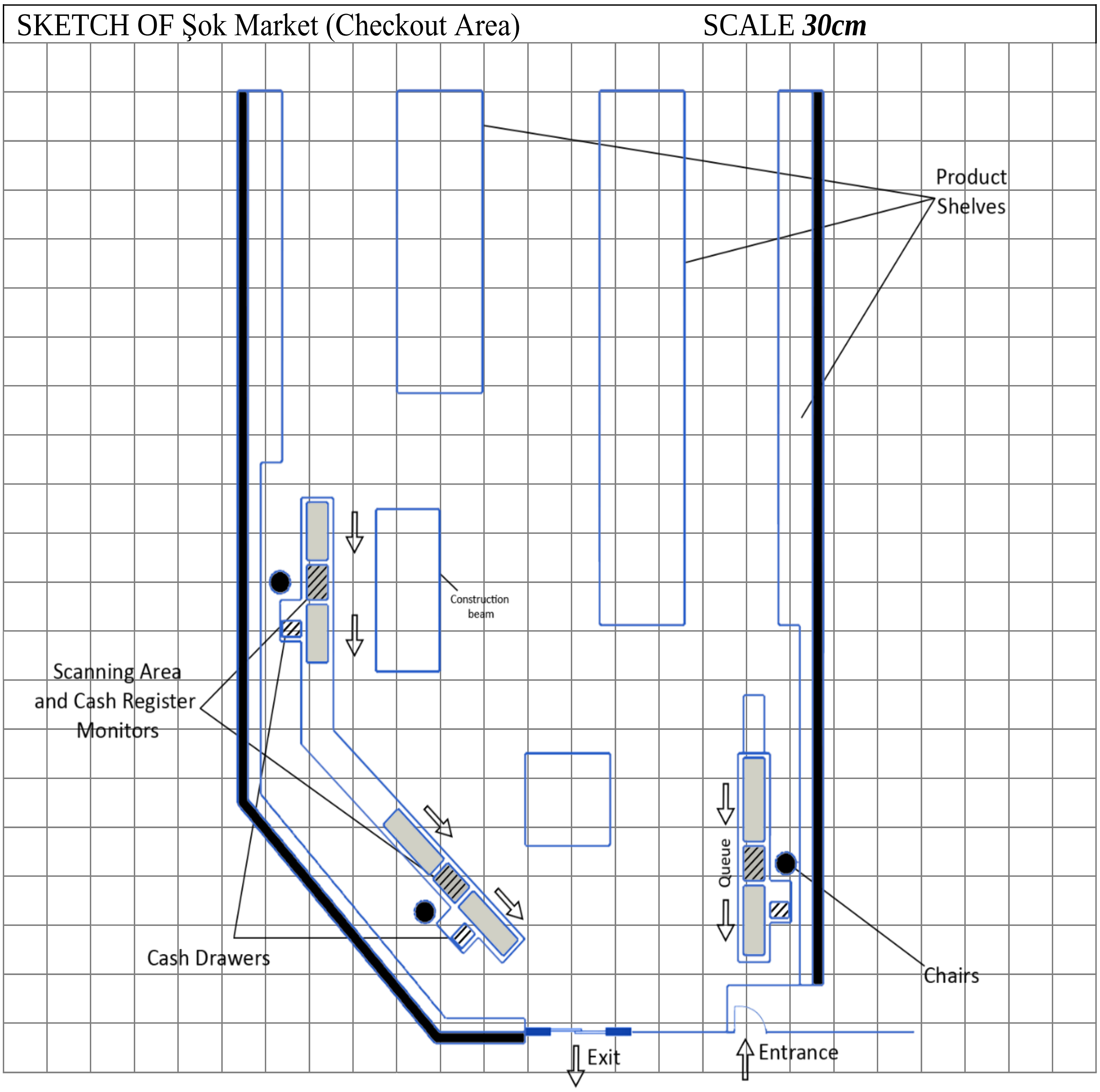
Appendix A



The layout is a cut-out of the full-scale layout, since the rest of the facility layout is not important for the cashier workspace. What matters is the part that may affect customers' interaction with the cashiers and queues and how they line up before checking out.

The promotion items shelf (the block in the middle bottom) and the construction beam are blocking the view of the customers coming from the right lane, and thus cannot see the cash western registers.

If a self-checkout machine were to be placed, it would most optimally be placed instead of the promotion items shelf in the middle, since it is close to the exit and doesn't obstruct the working area of the cashiers.

A layout change, however, will need to work around the construction beam. There are many ways the layout can be changed to and each way can affect customer behavior differently. For example, placing the cash registers closer to northern side might cause customers to check-out before viewing the products in the rest of the facility.

Appendix B

Study No 1

ELEMENTS	UPPER LINE:SUBSTRACTED TIME								
	1	2	3	4	5	6	7	8	9
Arrivals (Not Crowded) (26 Data Points)	12	55	107	42	194	92	39	94	74
	00:00:12	00:01:07	00:02:54	00:03:36	00:06:50	00:08:22	00:09:01	00:10:35	00:11:49
	31	103	14	98	69	46	55	95	74
	00:20:03	00:21:46	00:22:00	00:23:38	00:24:47	00:25:33	00:26:28	00:28:03	00:29:17
Arrivals (Crowded) (40 Data Points)	58	22	64	23	17	51	109	2	7
	00:57.6	01:19.5	02:23.1	02:46.6	03:03.2	03:54.6	05:44.0	05:46.2	05:53.5
	26	47	29	27	36	24	47	26	22
	12:44.7	13:31.4	14:00.4	14:27.9	15:03.5	15:27.1	16:13.6	16:40.1	17:02.3
	43	28	32	19	12	36	19	36	21
	22:41.4	23:09.0	23:41.2	24:00.2	24:12.6	24:48.3	25:07.1	25:43.2	26:04.5
Service Time (Not Crowded) (15 Data Points)	80.0	28.5	54.4	59.4	62.1	34.8	47.0	22.0	78.0

Sheet of Sheets

LOWER LINE: READING						MIN TIME	AV. TIME	SLCTD TIME	RATING	NORMAL TIME
10	11	12	13	14	15					
40	128	78	86	53	78	12	71.19	71.19	-	-
00:12:29	00:14:37	00:15:55	00:17:21	00:18:14	00:19:32					
33	61									
00:29:50	00:30:51									
60	151	60	34	16	66	2	40.35	40.35	-	-
06:53.0	09:24.0	10:23.6	10:57.5	11:13.2	12:18.8					
50	48	38	40	23	98					
17:52.7	18:40.5	19:18.3	19:57.9	20:21.2	21:58.8					
47										
26:51.7										
54.0	74.0	64.0	41.0	88.0	83.6	22.0	58.05	58.05	100%	58.05

Since the rate is assumed to be at 100%, then the normal time is $T_n = \frac{T_c}{100\%} = T_c$, where T_c is the average cycle time, which is found from the averages of the observations from the observation sheet.

Since a cashier rests when no customers are present, their PFD times coincide with the time when there is no job to be done in the first place. As such, calculating the standard time may not be as meaningful in this case as the case in a manufacturing facility or other types of service facilities.

Appendix C

Average number of people in the queue:

$$Arrival\ rate = \lambda$$

$$Number\ of\ servers = s$$

$$Service\ rate = \mu$$

$$Utility\ factor = \rho = \frac{\lambda}{\mu s} = \frac{\lambda}{\mu_{eff}}$$

$$Average\ number\ of\ people\ in\ the\ queue = L = \sum_{n=0}^{\infty} nP_n \approx \frac{\rho}{1-\rho}$$

Where P_n is the probability of n people being in the system.

It is not feasible to have ∞ people in the system, since it is a real-life scenario in a finite bounded area, but for the purpose of the calculation, limiting the capacity of the queue to a high number (10, 12, etc.) will produce extremely close results to the case of an unlimited capacity.

$Average\ waiting\ time = W = \frac{L}{\lambda}$ by Little's Law

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$\rho_{nc} \approx 0.82$	$\rho_c = 0.901$
$L_{nc} = \frac{\rho_{nc}}{1-\rho_{nc}} = 4.556$	$L_c = \frac{\rho_c}{1-\rho_c} = 9.101$
$W_{nc} = \frac{L_{nc}}{\lambda_{nc}} \times 60 \frac{mins}{hr}$ = 5.4 minutes	$W_c = \frac{L_c}{\lambda_c} \times 60 \frac{mins}{hr}$ = 6.12 minutes

Appendix D

Engineering economy tool can be utilized to find the present worth (current worth of money excluding the effect of time and interest rates). This assumes that minimum wage remains constant and that inflation rate is zero, however.

$$PW_{self-checkout} = Purchasing\ Cost + Annual\ Maintance\ Cost * \left(P/A\,, i_{year}, n\right)$$

$$PW_{self-checkout} = 50000₺ + 5000₺ * (P/A\,, 20\%, 5)$$

$$PW_{self-checkout} \cong 64953\ ₺$$

$$PW_{employee} = Monthly\ Wage * (P/A,\ i_{month},\ n * 12)$$

$PW_{employee} = 8500₺ *\ (P/A, 1.531\%, 60)$ [Over 5 years]

$$PW_{employee} \cong 332085₺$$