PAPER • **OPEN ACCESS**

Inventory and Transportation Model for Decision Making in Cement Industry (Case study at PT Semen Padang)

To cite this article: Daniel Eko Sulistyo *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **505** 012084

IOP Conf. Series: Materials Science and Engineering **505** (2019) 012084 doi:10.1088/1757-899X/505/1/012084

Inventory and Transportation Model for Decision Making in Cement Industry (Case study at PT Semen Padang)

Daniel Eko Sulistyo [1], **Jonrinaldi** [1] **and Alexie Herryandie** [1]

[1] Department of Industrial Engineering, Andalas University, Padang, Indonesia

Abstract. To survive the cement business competition, logistics strategy becomes one of the key factors. Demand fluctuations force companies to make dynamic decision. Any logistic operation decisions determine amount of total cost. Decision of production method can determine both inventory cost and stock out cost. In the other side, decision of transport order determine transport cost, inventory cost and stock out cost. PT Semen Padang is one of companies that produce and trade cement and clinker with 10,400,000 ton cement production capacity per year. Currently, most of cement production is done in Indarung (about 25,000 ton per day), in mass production to prevent stock outs. Customer demand is supplied by land routes that begins from Indarung and sea route that begins from Teluk Bayur. Cement freight from Indarung to Teluk Bayur is used bulk train and bulk truck. PT Semen Padang cooperate with PT Kereta Api Indonesia where there are transport targets for a period which if not achieved, then PT Semen Padang still has to pay a number of targets. The authors believes that there must be something that can be used to determine what should be the order of production and transportation at one time (daily), so that the optimal cost in a period is reached. The authors do the system modelling and descriptions of the required parameters so that the mathematical formulation can be compiled to be applied to the computer simulation that can be used by logistics manager to take operational decisions.

1. Introduction

To survive the business competition, the right strategy becomes one of the most key factors. Every business has the characteristics of its competitors, its consumers, its products and its own transport. So for different business, the strategy used must be different. Cement business has a low value per weight product, so the logistics cost becomes a considerable cost component. Any logistic operation decisions determine the amount of total cost. Factories with production capacity and market demand tend to be more appropriate to use mass production system, so guarantee of availability of goods can be ascertained. In contrast factory that produce special products with demand not too large compared to production capacity can be used just-in-time system, with careful planning to achieve lean manufacturing and customer satisfaction. In the case of production capacity constraints compared to the number of demands, the company may consider to keep producing itself (with stock out risk) or outsourced to other manufacturers to ensure stock availability in the market. In the case of factories and market balance demands, consideration should be given to avoid stock outs in the market by increasing safety stock or minimizing inventory with the risk of a time being stock out when demand is rising and the plant is not ready for production. Naturally, the company will implement safety stocks for major markets, where margins and sales quantities are high and tend to ignore stock outs in support markets, but the difficulty of finding market share in an area or supply guarantee contracts sometimes requires companies to let both markets stock out at the same time. The fulfilment of large quantities of demand

IOP Conf. Series: Materials Science and Engineering **505** (2019) 012084 doi:10.1088/1757-899X/505/1/012084

at any given time to use the entire transportation capacity owned, consequently there is a greater increase in transportation costs compared to the amount of goods sent due to the different modes of transportation used.

PT Semen Padang is a company that produces and trades cement and clinker. The Semen Padang factory is located in Indarung and Dumai with a capacity of 10,400,000 tons per year. In this paper, the authors just discuss cement factory in Indarung that produce cement about 25,000 tons per day, mass-producing cement production for general cement type (PCC and OPC) and just in time for special type (PPC, Type V, OWC). The main process of cement production is divided into raw material preparation, raw mix production, fuel preparation, clinker production, cement production and product (cement or clinker) preparation to supply consumers demand. Cement distribution activity by land routes begins from Indarung Packing Plant, while cement distribution activity by sea route starts from Teluk Bayur Packing Plant, by firstly transporting from Indarung to Teluk Bayur. The freight used is truck and train, with delivery capacity for train is 12 trips × @ 24 carriages × @ 25 t = 7000 t per day and the delivery capacity for truck is 273 trips × @ 22 t = 6000 t per day. Logistics strategy starts from Indarung and Teluk Bayur, where almost all cement distribution activities start from here. Monthly sales forecasting by land routes and sea route and daily realization monitoring is necessary to execute any inventory & transport decisions of cement in Indarung and Teluk Bayur silos. Stock out is not permitted at all, as it will threaten market share and customer satisfaction. For distribution and transport efficiency, product availability waiting time should be as minimum as possible. Fluctuation of cement demand by land and sea route, unpredictable machine breakdown time, silos loading and unloading facilities capacity, shipping capacity and storage of Indarung and Teluk Bayur silos are important issues to minimize the occurrence of stock out of cement in Indarung and Teluk Bayur. The phenomenon of stock out in Indarung is often caused by unpredictable factory breakdown, while existing stock is "already" sent to Teluk Bayur. The phenomenon of stock out in Teluk Bayur is often caused by transport capacity of Indarung to Teluk Bayur, while the demand of cement by land is slightly.

Inventory cost is the cost required in a stock can be seen from the main components that influence: investment costs, storage costs, obsession cost and cost of quality [20]. Similar research on inventory management with the object of oil product. Because storage is in the tank and no special treatment (handling and transport) is required on the stored product, inventory cost is not a major cost[19]. Problem of inventory optimization can be converted into another problem called modular proportional flow problem in multi period and multi echelon, where the goal is to minimize the cost network flow problem by considering other constrains[1]. The problems faced to achieve the optimization of stock is influenced by the demand for the stock. Demand is the number of units taken from stock or stock. Demands are categorized by their number, level and pattern. The amount of demands in each period can be in the same amount (constant) or in different amounts in each period [24]. Dynamic determinism occurs when the amount of product demand is known with certainty but with different amounts in each period and the standard deviation value is zero. Dynamic determinism can be solved with optimization approach and heuristic approach. There are several heuristic approaches that can be used, such as Algorithm Wagner-Within (AWW), silver meal, lot for lot (LFL), least total cost, and least unit cost [25]. A demand is said to be the probabilistic if the number of unknown demands yet follows a certain distribution pattern and with a standard deviation value not equal to zero. The probabilistic demand problems cause there must be a safety inventory or so-called safety stock [13]. A demand is said to be uncertainty if the amount of the demand is unknown and does not follow the pattern of a distribution as well as with a standard deviation value not equal to zero. One of the methods that can be used is the periodic review (R, s, S) power approximation method [16].

Mode of transportation is a distribution of transportation models that can be used to move an item from one place to another. In determining the best transportation in accordance with the objectives to be achieved then it is necessary to analyse the type of transportation used and the amount of use per each type [23]. Transportation is an important part because the production process is not done in all places.

The transport network designed in such a way makes it possible to achieve a high level of responsiveness at low cost [4]. Transportation management is the overall activity in the framework of planning, directing and controlling the movement service (goods and people) to achieve corporate logistics goals. Transport management can be viewed as a special function that focuses on physical delivery of goods and passengers and executive functions [18].

Forecasting is an activity undertaken to estimate the quantity of a product to be traded or used for the future period in order to know the exact quantity of product to be produced [5]. In determining the right method for a forecast based on time series, then there are some steps that must be considered as by considering the data pattern used [14]. Based on the data pattern obtained can be used method moving average, exponential smoothing and regression [3]. Stock out is a condition that is not expected to occur in a company because it can harm the company [22]. The losses caused by stock outsets make the manufacturing companies strive to get out of this problem, by raising the level of safety stock up to maximum level or mass production[12]. Mass production is a production that focuses on manufacturing in large quantities essentially to produce the maximum number of products in one lot [15]. Safety stock is defined as the inventory required to prevent stock outs on fluctuating demand conditions and forecasts are inaccurate. But that does not mean all stock out potential is met from safety stock, depending on how big the service level is set[11]. Previous research developed a multi-periods Decision Support System (DSS) model for optimization of cement allocation and logistic planning at a large cement plant in India with a large distribution area [21]. To get the right decision, can be used linear programming. Some industries that use linear programming are transportation, energy, telecommunication and factories. In addition, it is useful in modelling the issues of planning, routing, scheduling, allocation and design [17]. Other similar research has been done by minimizing inventory and transportation costs, with certain types of products, supply from multiple sources, supplying some customers, but no minimum transport and constraint costs [10]. Coordination mechanisms have been discussed in research related to green manufacturers that involve many players so that flow of raw materials, parts, finished products and returned products is optimal [7]. By integrating the production process and inventory cycle, inventory cost savings can be made on the closed supply chain [6]. Mathematical modeling has been done on production, inventory and transportation decision in green industry by using mixed-integer nonlinear programming model [8]. Portland cement is a hydraulic cement produced by grinding the Portland Clinker which consists mainly of calcium silicate with other additives [2]. Previous research mentioned that there is a significant influence between the duration of storage of cement with the reduction of the compressive strength of cement. To maintain the quality of cement is recommended normal storage no more than 3 (three) months [9].

2. Methods

This research method is part of operations research. The research begins by summarizing the problems that exist in the transportation and inventory operations of bulk cement Indarung and Teluk Bayur silos. In this step the authors to inventory any case that has been used to determine the decision, that is by dividing the criteria of Indarung and Teluk Bayur silos stock into 3 categories that is critical, normal, and full. Furthermore, alternative solutions for these 9 conditions are expected to result in the lowest total operational cost in terms of inventory, transportation and stock out. Research continued by identifying the problem, done by explaining the characteristics of the system designed that can be seen in Figure 1. In this study, the system under study is the process of storage and distribution of products after production, to meet consumer demand. The plant produces cement at the order of production and a maximum of 25,000 tons per day according to factory capacity. Seen that the monthly factory production realization is unstable, tend to be low at the beginning of the year, and tend to be high at the end of the year. The factory-manufactured cement is stored in the Indarung silos. Silos stock can be monitored daily, either by direct measurement or from historical data. It is seen that the monthly cement stock in Indarung silos tends to be high at the beginning of the year and low at the end of the year. The high stock of cement at the beginning of this year that causes the production of cement tend to be low,

IOP Conf. Series: Materials Science and Engineering **505** (2019) 012084 doi:10.1088/1757-899X/505/1/012084

that is because the silos is full. Stocks in the Indarung silos are used to meet the demand of Indarung to meet consumer needs by land route. Seen that there is no stock out at the beginning of the year, but it increases at the end of the year. It can be explained that at the end of the year stock began to be critical, and production capacity was unable to meet the demand.

On a regular basis the stock is transferred from Indarung silos to Teluk Bayur silos by using truck and train. The amount of cement shipped by the transport order and the maximum of the transportation capacity is 7,000 tons per day for train plus 6,000 tons per day for the truck. It is seen that the amount of cement transported at the beginning of the year tends to be smaller than the end of the year. The factory manufactured cement is stored in the Indarung silos. Stock silos can be monitored daily, either by direct measurement or from historical data. It can be seen that the monthly cement stock in Teluk Bayur silos tends to be high at the beginning of the year and low at the end of the year. The high stock of cement at the beginning of the year is what causes the transport of cement tends to be low, that is because the silos is full. Stock in Teluk Bayur silos is used to fulfil the demand of Teluk Bayur to fulfil consumer needs through sea routes. Seen that there is no stock out at the beginning of the year, but it increases at the end of the year. It can be explained that at the end of the year stock began to be critical, and production and transportation capacity were unable to meet the demand.

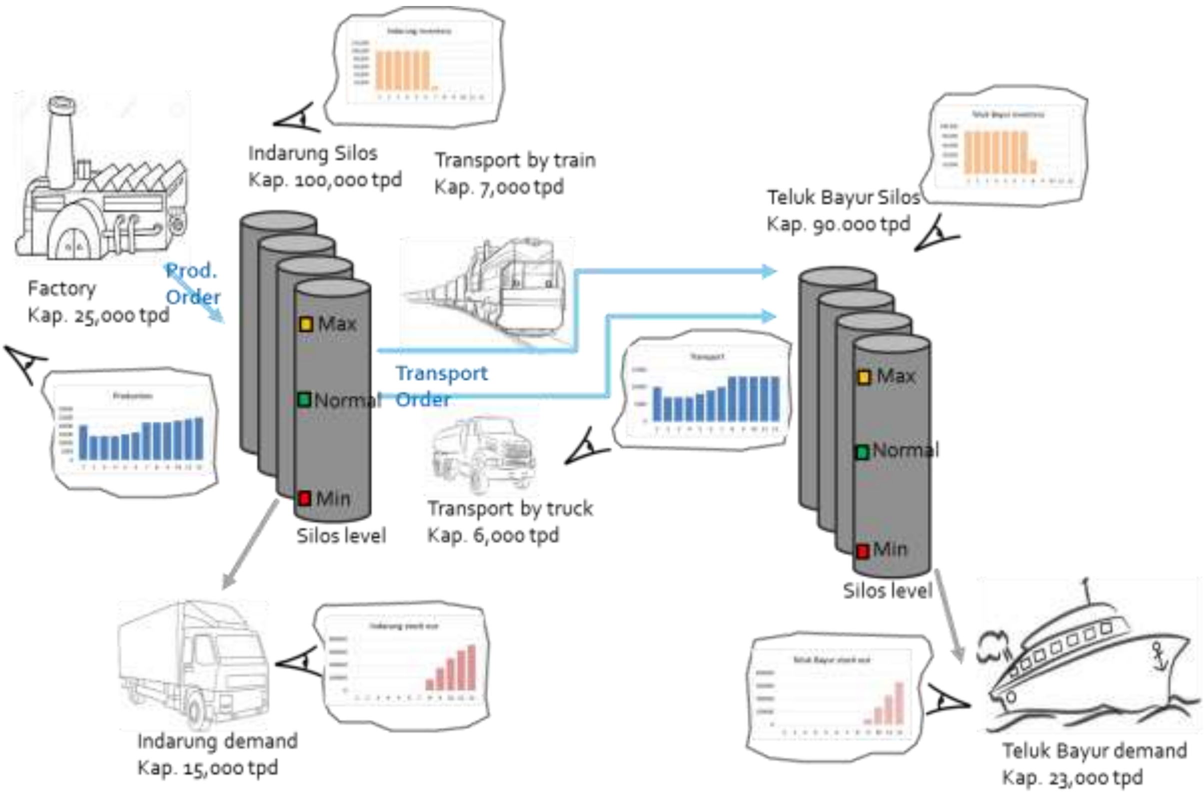


Figure 1. System Characteristic.

3. Result and discussion

Furthermore, complete descriptions of system parameters have been formulated to be developed into a mathematical model. Parameters that must exist in the mathematical formula will be index, control input, global input, process and output. Index parameters are day (t) and type cement (k). The use of this index is intended to facilitate the writing of formulas and calculations. Control input parameters are production orders (P_{kt}), transport orders for truck (TF_{kt}) and transport orders for truck (TR_{kt}). Global input

IOP Conf. Series: Materials Science and Engineering **505** (2019) 012084 doi:10.1088/1757-899X/505/1/012084

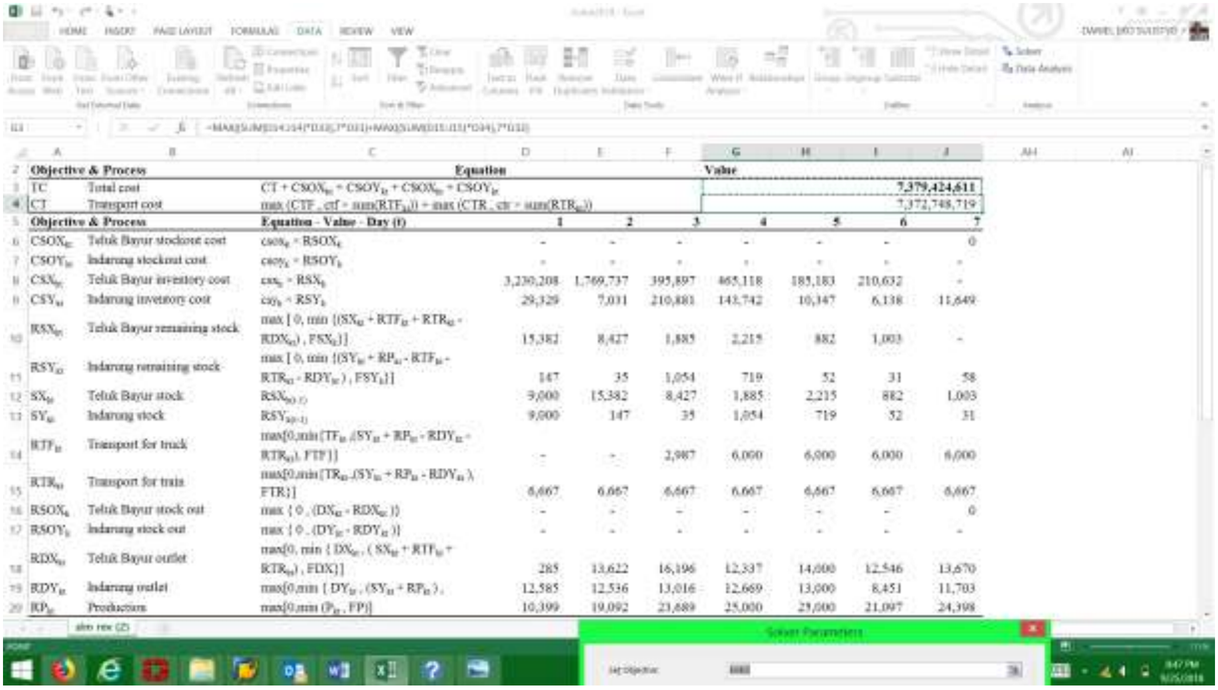
parameters are inventory unit cost Teluk Bayur (csx_k), inventory unit cost Indarung (csy_k), stock out unit cost Teluk Bayur ($csox_k$), stock out unit cost Indarung($csoy_k$), cost of minimum transport for truck (CTF), cost of minimum transport for train (CTR), transport unit cost for truck (ctf), transport unit cost for train (ctr), production capacity (FP), Teluk Bayur silos capacity (FSX_k), Indarung silos capacity (FSY_k), Teluk Bayur outlet capacity (FDX), Indarung outlet capacity (FDY), transport capacity for truck (FTF), transport capacity for train (FTR), Teluk Bayur demand (DX_{kt}) and Indarung demand (DY_{kt}). Process parameters are auxiliary parameters to connect between input and output. Process parameters are transport cost (CT), Teluk Bayur stock out cost ($CSOX_{kt}$), Indarung stock out cost ($CSOY_{kt}$), Teluk Bayur Inventory cost (CSX_{kt}), Indarung inventory cost (CSY_{kt}), Teluk Bayur stock (SX_{kt}), Indarung stock (SY_{kt}), Teluk Bayur remaining stock (RSX_{kt}), Indarung remaining stock (RSY_{kt}), transport for truck (RTF_{kt}), transport for train (RTR_{kt}), Teluk Bayur stock out ($RSOX_{kt}$), Indarung stock out ($RSOY_{kt}$), Teluk Bayur outlet (RDX_{kt}), Indarung outlet (RDY_{kt}) and production (RP_{kt}). The output parameter is the result to be achieved, that is total cost (TC).

What will be achieved by this system is the optimization of total cost (TC) while still considering various operational constraints, i.e. production capacity (FP), Teluk Bayur silos capacity (FSX_k), Indarung silos capacity (FSY_k), Teluk Bayur outlet capacity (FDX), Indarung outlet capacity (FDY), transport capacity for truck (FTF), transport capacity for train (FTR). We know that total cost (TC) is the sum of transport cost (CT), Teluk Bayur stock out cost ($CSOX_{kt}$), Indarung stock out cost ($CSOY_{kt}$), Teluk Bayur inventory cost (CSX_{kt}), Indarung Inventory cost (CSY_{kt}). Transport cost (CT) is the cost incurred by the company to pay for the transport services of cement. Because the use of 2 (two) modes of transport (truck and train), then the calculation of transport cost adjusted with the modes used, namely cost of minimum transport (CTF or CTR) and transport unit cost (ctf or ctr). Transport cost is sum of truck cost and train cost. Truck or train cost is the largest value between cost of minimum transport (CTF or CTR) and multiplication transport unit cost (ctf or ctr) and transport (RTF_{kt} or RTR_{kt}). Teluk Bayur inventory cost (CSX_{kt}) is multiplication inventory unit cost Teluk Bayur (csx_k) and remaining stock (RSX_{kt}). Remaining stock (RSX_{kt}) is Teluk Bayur stock (SX_{kt}) plus transport (RTF_{kt} plus RTR_{kt}) minus Teluk Bayur outlet (RDX_{kt}). Remaining stock (RSX_{kt}) constraints are non negative and Teluk Bayur silos capacity (FSX_k). Teluk Bayur outlet (RDX_{kt}) is demand of Teluk Bayur (DX_{kt}). Teluk Bayur outlet (RDX_{kt}) constraints are non negative and available stock, Teluk Bayur stock (SX_{kt}) plus transport (RTF_{kt} plus RTR_{kt}). Teluk Bayur stock out cost ($CSOX_{kt}$) is multiplication Teluk Bayur stock out unit cost ($csox_k$) and Teluk Bayur stock out ($RSOX_{kt}$). Teluk Bayur stock out ($RSOX_{kt}$) is difference of demand Teluk Bayur (DX_{kt}) and Teluk Bayur outlet (RDX_{kt}). Teluk Bayur stock out ($RSOX_{kt}$) constraint is non negative. Teluk Bayur stock (SX_{kt}) is remaining stock from one day before ($RSX_{k(t-1)}$). Indarung inventory cost (CSY_{kt}) is multiplication inventory unit cost Indarung (csy_k) and remaining stock (RSY_{kt}). Remaining stock (RSY_{kt}) is Indarung stock (SY_{kt}) plus production (RP_{kt}) minus transport (RTF_{kt} plus RTR_{kt}) minus Indarung outlet (RDY_{kt}). Remaining stock (RSY_{kt}) constraints are non negative and Indarung silos capacity (FSY_k). Indarung outlet (RDY_{kt}) is demand of Indarung (DY_{kt}). Indarung outlet (RDY_{kt}) constraints are non negative and available stock, Indarung stock (SY_{kt}) plus production (RP_{kt}). Indarung stock out cost ($CSOY_{kt}$) is multiplication Indarung stock out unit cost ($csoy_k$) and Indarung stock out ($RSOY_{kt}$). Indarung stock out ($RSOY_{kt}$) is difference of demand Indarung (DY_{kt}) and Indarung outlet (RDY_{kt}). Indarung stock out ($RSOY_{kt}$) constraint is non negative. Indarung stock (SY_{kt}) is remaining stock from one day before ($RSY_{k(t-1)}$).

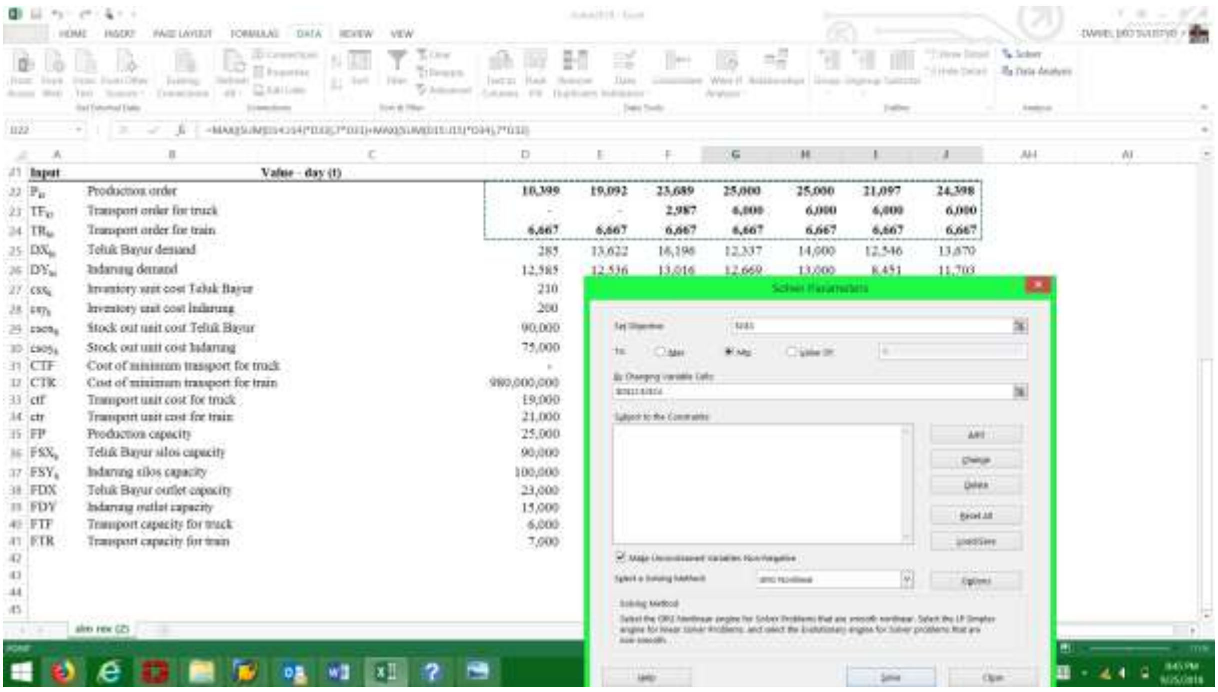
Numeric data is needed so that the simulation can represent the actual event. The numerical data used in this study is not real data because it is related to company secrets, but is a general assumption based on the authors knowledge and experience, so that the data entered make sense. The numerical data are expected to be used just for educational purposes, not businesses that will harm the company (PT Semen Padang). Teluk Bayur and Indarung demand data is taken from a random daily report. The product value (in Teluk Bayur or Indarung) is taken from the price of cement on the market minus distribution, transportation and marketing costs (about 15 percent). Inventory unit costs are about 15 percent multiplied by one per 365 days in a year multiplied by the product value. Stock out unit cost data is

IOP Conf. Series: Materials Science and Engineering **505** (2019) 012084 doi:10.1088/1757-899X/505/1/012084

taken from potential loss of profit (about 15 percent from product value). Cost of minimum transport is taken from real condition but not the real number. Transport unit cost is taken from real condition but not the real number. Production capacity, Teluk Bayur silos capacity and Indarung silos capacity is general information. Teluk Bayur outlet capacity, Indarung outlet capacity and transport capacity is based on authors experience.



Objective & Process		**Equation**				**Value**			
TC	Total cost	$CT + CSOX_{kt} + CSOY_{kt} + CSOX_{kt} + CSOY_{kt}$							7,379,424,611
CT	Transport cost	$\max(CTF, ctf \times sum(RTF_{kt})) + \max(CTR, ctr \times sum(RTR_{kt}))$							7,372,748,719
Objective & Process		**Equation - Value - Day (t)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
$CSOX_{kt}$	Teluk Bayur stockout cost	$csox_k \times RSOX_k$	-	-	-	-	-	-	0
$CSOY_{kt}$	Indarung stockout cost	$csoy_k \times RSOY_k$	-	-	-	-	-	-	-
CSX_{kt}	Teluk Bayur inventory cost	$csx_k \times RSX_k$	3,230,208	1,769,737	395,897	465,118	185,183	210,632	-
CSY_{kt}	Indarung inventory cost	$csy_k \times RSY_k$	29,329	7,031	210,881	143,742	10,347	6,138	11,649
RSX_{kt}	Teluk Bayur remaining stock	$\max[0, \min\{(SX_{kt} + RTF_{kt} + RTR_{kt} - RDX_{kt}), FSX_k\}]$	15,382	8,427	1,885	2,215	882	1,003	-
RSY_{kt}	Indarung remaining stock	$\max[0, \min\{(SY_{kt} + RP_{kt} - RTF_{kt} - RTR_{kt} - RDY_{kt}), FSY_k\}]$	147	35	1,054	719	52	31	58
SX_{kt}	Teluk Bayur stock	$RSX_{k(t-1)}$	9,000	15,382	8,427	1,885	2,215	882	1,003
SY_{kt}	Indarung stock	$RSY_{k(t-1)}$	9,000	147	35	1,054	719	52	31
RTF_{kt}	Transport for truck	$\max[0,\min\{TF_{kt}, (SY_{kt} + RP_{kt} - RDY_{kt} - RTR_{kt}), FTF\}]$	-	-	2,987	6,000	6,000	6,000	6,000
RTR_{kt}	Transport for train	$\max[0,\min\{TR_{kt}, (SY_{kt} + RP_{kt} - RDY_{kt}), FTR\}]$	6,667	6,667	6,667	6,667	6,667	6,667	6,667
$RSOX_k$	Teluk Bayur stock out	$\max\{0, (DX_{kt} - RDX_{kt})\}$	-	-	-	-	-	-	0
$RSOY_k$	Indarung stock out	$\max\{0, (DY_{kt} - RDY_{kt})\}$	-	-	-	-	-	-	-
RDX_{kt}	Teluk Bayur outlet	$\max[0, \min\{DX_{kt}, (SX_{kt} + RTF_{kt} + RTR_{kt}), FDX\}]$	285	13,622	16,196	12,337	14,000	12,546	13,670
RDY_{kt}	Indarung outlet	$\max[0,\min\{DY_{kt}, (SY_{kt} + RP_{kt}),$	12,585	12,536	13,016	12,669	13,000	8,451	11,703
RP_{kt}	Production	$\max[0,\min(P_{kt}, FP)]$	10,399	19,092	23,689	25,000	25,000	21,097	24,398



Input	**Value - day (t)**							
P_{kt}	Production order	**10,399**	**19,092**	**23,689**	**25,000**	**25,000**	**21,097**	**24,398**
TF_{kt}	Transport order for truck	-	-	**2,987**	**6,000**	**6,000**	**6,000**	**6,000**
TR_{kt}	Transport order for train	**6,667**	**6,667**	**6,667**	**6,667**	**6,667**	**6,667**	**6,667**
DX_{kt}	Teluk Bayur demand	285	13,622	16,198	12,337	14,000	12,546	13,670
DY_{kt}	Indarung demand	12,585	12,536	13,016	12,669	13,000	8,451	11,703
csx_k	Inventory unit cost Teluk Bayur	210						
csy_k	Inventory unit cost Indarung	200						
$csox_k$	Stock out unit cost Teluk Bayur	90,000						
$csoy_k$	Stock out unit cost Indarung	75,000						
CTF	Cost of minimum transport for truck	-						
CTR	Cost of minimum transport for train	980,000,000						
ctf	Transport unit cost for truck	19,000						
ctr	Transport unit cost for train	21,000						
FP	Production capacity	25,000						
FSX_k	Teluk Bayur silos capacity	90,000						
FSY_k	Indarung silos capacity	100,000						
FDX	Teluk Bayur outlet capacity	23,000						
FDY	Indarung outlet capacity	15,000						
FTF	Transport capacity for truck	6,000						
FTR	Transport capacity for train	7,000						

Figure 2. Computer simulation.

Simulation is done by using 'solver' in Microsoft Excel 2010 with a duration of 7 days (weekly) with result an optimal value for total cost objective is about 7.3 billion rupiah. To obtain an optimal result,

IOP Conf. Series: Materials Science and Engineering **505** (2019) 012084 doi:10.1088/1757-899X/505/1/012084

operational decisions must be taken. From Figure 2, it can be seen that the decision taken is to adjust production orders and transportation orders with the demand for Teluk Bayur and Indarung at this time and the next. The transportation cost component is mostly used in constant values for train (about 6,600) and fluctuate values for trucks according to Teluk Bayur demand (zero in first until second day and 6,000 in third until last day). Transport using the train does have significant cost consequences, cost of the minimum transport (980,000,000) and higher unit costs (21,000), on the other hand the train provides a higher transport capacity (7,000), so it can prevent stock out in Teluk Bayur. Transport using the truck does not have significant cost consequences, no cost of the minimum transport and cheaper unit costs (19,000), on the other hand the truck provides a lower transport capacity (6,000). The component of stock out costs is minimal (zero), it is mean that all demands are met, because all demands are below the capacity of the outlet. Stock out cost is more expensive than inventory cost, so that stock out should be given more attention by logistic manager. The component of inventory costs are minimum, but still exists to meet demand in the next periods. Teluk Bayur stock out and inventory unit cost is more expensive than Indarung, so that amount of teluk Bayur remaining stock must be minimized.

4. Conclusion

To get the best logistic decision, it is necessary to see the goal to be achieved, that is optimizing the total cost for a period, while keeping in mind the operational constraints. Generally every optimization problem can be solved by linear program, but for optimization of company decision, which is the number of variable and and limiting that many, need to do system modeling and simulation. The authors have successfully designed the model with its parameter description, mathematical formulation and computers simulation in short period (weekly), for the next can be develop with the computer application in long period (annually) to be used by the logistics operational manager in decision making.

5. References

[1] B, Ufuk and F, Orhan. 2010. *Inventory allocation in multi-period multi-echelon logistics networks of modular products*. Tunisia : 8th International Conference of Modeling and Simulation

[2] Badan Sertifikasi Nasional (2015). SNI 2049:2015 semen portland. Jakarta: Badan Sertifikasi Nasional

[3] Chapman, Stephen N. 2006. *The fundamentals of production planning and control*. New Jersey: Pearson Prentice Hall.

[4] Chopra, Sunil. 2010. *Supply chain management: strategy, planning, and operation*. New Jersey: Pearson Education Inc.

[5] Gaspersz, Vincent. 1998. *Production planning and inventory control*. Jakarta: PT. Sun.

[6] Jonrinaldi, Rahman T and Zhang D Z . 2018 . *An integrated model of production and inventory cycles of new and reusable bottling packages in a closed supply chain* . International Journal of Logistics Systems and Management 30 (2) 246-267

[7] Jonrinaldi, Zhang D Z . 2010 . *Optimal integrated production and inventory cycles in a whole green manufacturing supply chain network with coordination* . Computers and Industrial Engineering (CIE) 2010 40th International Conference on, pp. 1-6

[8] Jonrinaldi, Zhang D Z . 2017. *An integrated production, inventory & transportation decision in a whole green manufacturing supply chain* . International Journal of Industrial and Systems Engineering 25 (4) 520-544

[9] K M, Lovely and Chacko, Anniamma. 2013. *A study on strength characteristics of ordinary portland cement due to storage*. International Journal of Innovative Research in Science, Engineering and Technology.

[10] Krishnakumari, G . 2016 . *Formulation of a combined transportation and inventory optimization model with multiple time periods* . Hyderabad, India : Int. Journal of Engineering Research and Applications

[11] L. King. 2011. *Understanding safety stock and mastering its equations*. APICS Magazine, July/August 2011.

[12] Lahindah, Laura dkk. 2014. *Stock out analysis: An empirical study on forecasting, re-order point and safety stock level at PT.Combiphar, Indonesia*. Indonesia. No. 1, Vol. 3.
[13] Limansyah, Taufik dan J. Dharma Lesmono. 2012 . *Model persediaan probabilistik satu jenis barang dengan melibatkan faktor all unit discount* . Bandung : Lembaga Penelitian dan Pengabdian kepada Masyarakat Universitas Katolik Parahyangan
[14] Makridakis. 1999. *Metode dan aplikasi peramalan*. Edisi 2. Jakarta : Binarupa Aksara.
[15] Micietova, Maria. 2011. *Lean production, lean vs. mass production, TPM as a tool of lean production*. Slovakia: University Of Zilina. Number 5, Volume VI
[16] Porras, E., & Dekker, R. 2008. A*n inventory control system for spare parts at a refinery: An empirical comparison of different reorder points methods*. European Journal of Operation Research, 184(1), 101-132.
[17] Rajeyan, Kourosh dkk. 2013. *Using linear programming in solving the problem of services company's costs*. Iran: Islamic Azad University. Singaporean Journal Of Business Economics, And Management Studies Vol.1, No.10.
[18] Reinhold, Stephan dkk. 2015. *The intellectual structure of transportation management research: A review of the literature.* SBB Lab University of St. Gallen
[19] Relvas, dkk. 2012. *Integrated scheduling and inventory management of an oil products distribution system*. Omega the international journal of management science.
[20] Ryzin, Garrett J. Van. 2001. *Analyzing inventory cost and service in supply chains*. Columbia: Columbia Business School.
[21] Sahoo, dkk. 2011. *A multi-period optimization model for cement production, allocation and logistics planning*. Mumbai : SOM Conference 2011 at NITIE.
[22] Sampaio, Mauro, Ester Quirino Dias Sampaio. 2016. *Managerial response to stock outs: the effect of remedies on consumer behavior*. Brazil: Centro Universitário da FEI. Production, 26(1), 66-77.
[23] Tamin, Ofyar, Z. 2000. *Perencanaan dan permodelan transportasi*. Bandung, Indonesia: Penerbit ITB.
[24] Tersine, Richard J. 1994. *Principles of inventory and materials management*. Edisi Keempat. Prentice Hall, Inc. USA.
[25] Waters, Donald. 2003. *Inventory control and management*. England: Chicester.

Acknowledgments
The authors would like to thanks to PT Semen Padang and Andalas University employees who have supported with the preparation of this paper.