Profit Maximized Network Optimization at SAP System: A Real-life Implementation in Cement Industry

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Abstract: What if we told you that "you already have 27% of net profit trapped in your misleading business"? As common de facto state in production planning, subjective human judgments play a significant role on demand point:plant assignments at product replenishment and this is mostly driven by myopic transportation minimization paradigm, disregarding production and profitability determinants. In this paper, we propose an integer programming characterized Network Optimization solution to find global optimal assignments that maximize the profitability in terms of contribution margin or net profit by taking sales, transportation and production planning perspectives into account and concerning potential capacity constraints. According to the experimental results obtained at a real-life implementation in cement industry, Network Optimization solution increases contribution margin by an average value of 6.33% and net profit by 26.3%. Moreover, proposed solution architecture promises a seamless network optimization experience over a large canvas that wholistically integrates SAP system, optimization logic and Microsoft Power BI tiers. As a result, our clients can concentrate on more value adding operations such as variance analysis and what-if scenario evaluation rather than manual, time consuming and error-prone data preparation.

1 INTRODUCTION

In the last year, COVID19 imposed Schumpeter's gale "creative destruction" like business transformation to the organizations all around the world to adapt to the concept drifts and uncertainties emerged at the business environment. In this context, business planning solutions are crucial actors at this era such that, these products provide the capabilities to simulate various what-if scenarios to monitor potential bottlenecks emerged at organizational scarce sources, e.g. liquid capital, workforce and installed capacity, and to proactively response to customer demand fluctuations by unmanned sustainable business models.

Seemingly, one of the major issues at business planning solutions is the satisfaction of customer demand by the most appropriate production facility. As the state-of-art, subjective human judgments on demand point:plant assignments at product replenishment play a vital role and this assignment is driven by biased aspect solely based on transportation minimization. Additionally, hand simulation performed by process owners requires more effort on data preparation. Hence less variance analysis and what-if scenario evaluation are performed.

Network Optimization solution aims to find global optimal demand point:plant assignments that maximize total net profit or contribution margin objective value according to planned sales volume, unit sales price, unit transportation cost, unit variable and fixed production cost. Additionally, capacity constraints planned at plant or plant-product detail levels and demand satisfaction constraints are other determinants of the proposed approach.

Respectively, Network Optimization solution promises the harmonization of mathematical modelling with human insights. Hence, the myopic aspect over transportation minimization is extended towards profitability maximization and production capacity. As a result, process owners dedicate more effort on variance analysis and different what-if

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Figure 1: Fit Gap Analysis for Network Optimization Solution.

scenarios evaluation. According to business requirement analysis and the leverage effect promised by Network Optimization solution, fit gap analysis is performed as given in Figure 1.

The paper is organized as follows. Section 2 reviews the related work about network optimization and transportation minimization applications. Section 3 explains Network Optimization solution within the context of solution architecture and major phases of the proposed approach. Section 4 discusses the experimental results obtained at a real-life implementation in cement industry. The conclusion and future work are summarized in Section 5.

2 LITERATURE REVIEW

Literature review section fundamentally concentrates on the applications of maximizing profits, network optimization and minimizing transportation costs in various manufacturing industries.

Billal, Islam, Alam and Hossain (2015) considers the time value of money, cost variance due to the transportation mode and responsive supply chain in a single model. The multi-stage supply chain network design (SCND) model is designed for the organization that operates in cement industry and meets the customer demand at the divisional markets in Bangladesh. The Mixed Integer Linear Programming (MILP) is used in the SCND model. Sulistyo, Herryandie and Jonrinaldi (2019) explains system modelling and the required parameters to compile the mathematical model which is applied to computer simulation used by the logistics manager to make operational decisions. Dikos and Spyropoulou (2013) proposes a platform for optimization supply chains and planning that uses mathematical programming. The underlying platform uses a series of nested mathematical programs to model the supply chain operations. This platform determines optimal operational response to fluctuations in both demand and production, and then performs mid and long-term planning in the context of what-if scenario evaluation. Das, Adnan, Hassan and Rahman (2017) aims to understand the terms of logistics cost and optimization techniques by a cost-optimizing solver developed in Microsoft Excel. As a result of using optimization tools and techniques, it is shown in a comparative way that an organization can reduce overall logistics costs by identifying cost factors and using them correctly. Chukwuma and Chukwuma (2015) designs a model for capacity planning and scheduling using Linear Programming. The underlying model suggests the most efficient route that minimizes transportation costs for the cement producers.

The operations management technique of linear programming (LP) is integrated into a cost accounting information system in Excel as an add-in to maximize profit and minimize cost in (Togo, 2005). Similarly, a global supply chain optimization model that maximizes the after-tax profits of a multinational corporation is introduced in (Vidal & Goetschalckx, 2001). This research helps on simultaneous consideration of transferring prices, transportation cost allocation, inventory costs and their impact on the selection of international transportation modes. Oladejo, Abolarinwa, Salawu and Lukman (2019) examines to maximize the profit and reduce the costs using linear programming. As a result of this study, the underlying mathematical model determines which products should be produced and sold to maximize profit.

Vimal, Rajak and Kandasamy (2019) aims to maximize the total monetary gain and minimizing pollution such that, the profits generated by the sale of both reused and manufactured products, profits gained from recycling units, cost of processing, setup, and repair at the intake nodes, and transportation costs are totally considered during the linear programming model design. In (Samani & Mottaghi, 2006), the optimum design of municipal water distribution networks for a single loading condition is determined by the integer linear programming technique to design a water distribution system that satisfies all required constraints with a minimum total cost. Kostin et al. (2018) presents a mathematical approach with MILP formulation for optimizing and planning Brazilian bioethanol supply chains. This approach aims to maximize the net present value of the entire supply chain of the sugar and bioethanol industry in Brazil, and proposes the technology chosen for the optimal configuration of a bioethanol network and the flows of all raw materials and final products involved.

3 PROPOSED APPROACH

3.1 Solution Architecture

Solution architecture of Network Optimization solution consists of three layers: SAP BW system, optimization logic and Microsoft Power BI.

SAP BW system is the core component of Network Optimization solution. Major use cases such as data management, network optimization data pre-processing, optimization valuation and adhoc reporting are executed at this layer. The corresponding components and transactions are developed in ABAP programming language.

Optimization logic layer holds the network optimization mathematical modelling. This model searches for global optimal demand point:plant assignments that maximize the objective function, i.e. contribution margin or net profit. The corresponding integer programming (IP) based mathematical model is developed in R programming language. Majorly, `lpSolve` and `dplyr` packages are implemented.

Lastly, Power BI is the presentation layer that demonstrates various dashboards such as income statement and product or customer-based profitability analysis reports with zoom-in/out functionalities. These dashboards are based on the network optimization valuation view held at SAP BW system. Proposed solution architecture is given in Figure 2.

3.2 Phases

Network Optimization solution is composed of three major phases: data management, optimization and adhoc reporting. These phases are explained in detailed at the following sections.

3.2.1 Data Management

In data management phase, required input data for optimization is maintained in three ways such as customization, master and planning data.

Network Optimization solution is based upon a what-if paradigm which manages different potential circumstances (or variants) at planning data, e.g. sales volume, sales price, transportation cost and feasibility, production cost and feasibility, and lastly capacity constraints. Hence customization data is used for an active *version management*. In the context of version management, it is possible to make before versus after simulation variance analysis such that, while before simulation typed versions hold the process owner’s direct insights about demand point:plant assignments as the *ground truth*, after

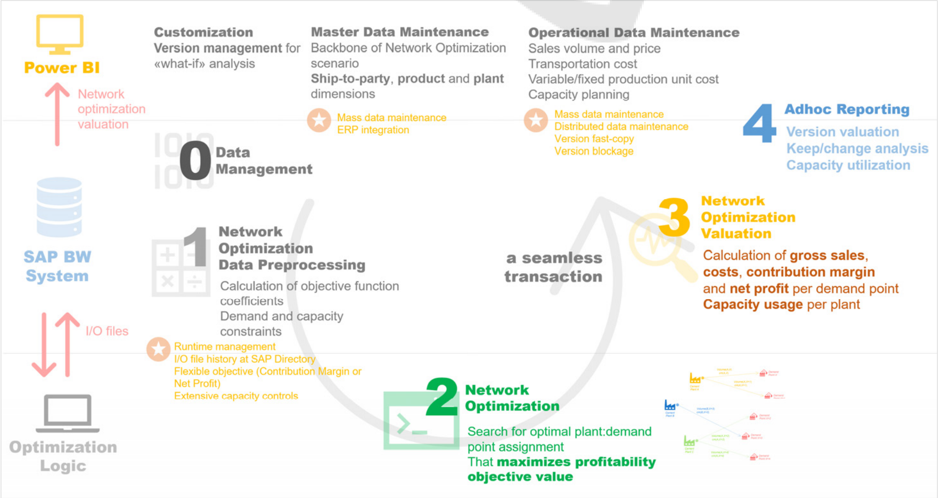


Figure 2: Proposed Solution Architecture. Process enhancements at the corresponding planning phases are denoted by yellow stars.

simulation typed versions purely reflect the global optimal assignments obtained by the underlying network optimization runs. As the relation between these two version types, demand point:plant assignments proposed at before simulation version is used as the baseline for unit transportation cost determination at delivered sales price conversion.

As the enhancement of Network Optimization solution, there is an *objective function type* feature at version customization step. This feature is used for designating objective function applied at network optimization such as contribution margin or net profit maximization. Distinctions and relations between before and after simulation type versions are given in Figure 3.

Master data constitutes the backbone of the proposed approach such that, it contains major *planning dimensions*, i.e. ship-to-party, product and plant. While these dimensions can be maintained individually via the corresponding data management user interfaces (UIs), it is also possible to export mass master data and import actual dimension members from SAP ERP system. Respectively, ship-to-party is a kind of dynamic dimension. Therefore, these alternative mass data maintenance interfaces and transactions are more effective for keeping ship-to-party dimension up-to-date. Details about planning dimensions are given as below:

- Ship-to-party dimension holds the major features of valid customers such as name, region, city, city district and micro-market.
- Product dimension contains the name, product type (bag or bulk cement) and segment (e.g. C1 strength level bag cement, C2 strength level bulk cement etc.) features.
- Plant dimension contains the name and active plant indicator features.

Planning data relatively reflects the what-if circumstances for the corresponding version. These circumstances can be designated by sales (e.g. sales volume and price), transportation (e.g. transportation cost) and production (e.g. variable or fixed production costs, capacity constraints at plant or plant-product detail levels) functional areas. Details about planning data management are given below:

- Sales volume (*vol*) and price (*prc*) planning step instantiates potential *demand points* (*dp*) which imply valid combinations of ship-to-party (*STP* set) and product (*PRD* set) dimensions as given in Equations 1 and 2.

  According to simulated/preset indicator at sales planning step, it is possible to determine whether the underlying demand point will be covered by network optimization or assigned to an apriori plant predefined at before simulation typed version. Additionally, sales process owner plans the exwork prices according to the unit transportation cost retrieved from before simulation typed version of the corresponding period and the delivered sales price determined at sales contract document.
- At transportation cost (*trs*) planning step, estimated unit transportation cost is planned on ship-to-party ($dp_i.stp$), product type ($dp_i.prd\_typ$) and plant basis (*plt*) as given in Equation 3. In the case of infeasible combinations that exceed the maximum distance threshold (approximately 400 kilometers), unit transportation cost is manually set as a big M value, e.g. one million ₺ per ton.
- Variable production cost (*vpc*) planning step holds the estimated variable production cost on product ($dp_i.prd$) and plant (*plt*) basis as given in Equation 4. This variable cost component reflects the production cost drivers that are directly correlated with the production volume such as direct material cost calculated according to the bill of material (BOM). In the case of infeasible production capability, unit variable production cost is manually set as a big M value, e.g. one million ₺ per ton.

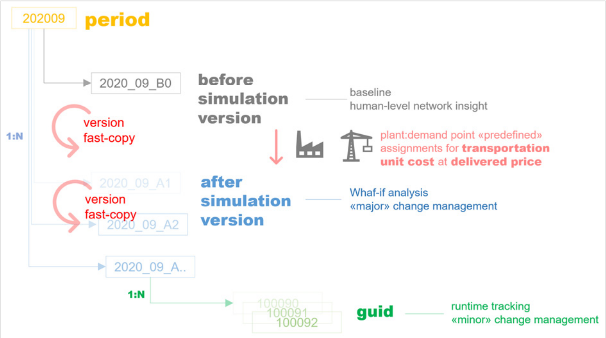


Figure 3: Distinctions and Relations between Before and After-simulation Typed Versions.

- Fixed production cost (*fpc*) planning step holds the estimated fixed production cost on plant (*plt*) basis as given in Equation 5. This fixed cost component reflects the production cost drivers that are not affected by the production volume but correlated with installed capacity such as amortization and direct labor cost calculated according to the production routing.

Sample planning user interfaces for sales, transportation and production planning steps are given in Appendix. Additionally, capacity constraints are other determinants handled at data management phase:

- Plant-based capacity planning step includes plant utilization rate, total capacity, and product type (bag or bulk) capacity figures on plant (*plt*) basis. These capacity figures per plant are revaluated on-the-fly by the utilization rate input.
- At product-based capacity planning step, capacity figures are specifically planned at product ($dp_i.prd$) and plant (*plt*) details. These product relevant capacity figures per plant are calculated on-the-fly by the utilization rate planned at previous plant-based capacity planning step.

3.2.2 Optimization

Optimization phase consists of three steps namely network optimization data pre-processing, optimization and valuation as shown in Figure 2.

In network optimization data pre-processing, three different input data, which are objective function coefficients ($coef_{dpi,pltj}$) for all demand point:plant combinations, demand satisfaction and capacity constraints, are all generated by using customization, master and planning data for the underlying version.

In the case of contribution margin maximization objective function preference for the underlying version, objective function coefficient ($coef_{dpi,pltj}$ in Equations 3-4) implies the sum of gross sales (Equation 2), transportation cost (Equation 3) and variable production cost (Equation 4) for each demand point(*dp*):plant(*plt*) combination. In the case of net profit maximization objective function preference, fixed production cost is also considered at objective function calculation as given in Equation 5. Underlying objective function coefficient calculation steps are given at Equations 2-5:

$$DP = STP \times PRD \tag{1}$$

$$gr\_sl_{dpi} = vol_{dpi} \times prc_{dpi} \tag{2}$$

$$coef_{dpi,pltj} = gr\_sl_{dpi} - vol_{dpi} \times trs_{dpi.stp,dpi.prd\_typ,pltj} \tag{3}$$

$$coef_{dpi,pltj} = coef_{dpi,pltj} - vol_{dpi} \times vpc_{dpi.prd,pltj} \tag{4}$$

$$coef_{dpi,pltj} = coef_{dpi,pltj} - vol_{dpi} \times fpc_{pltj} \tag{5}$$

Demand satisfaction constraint holds the planned sales volumes of the demand points that are set as simulated at simulated/preset indicator. In other words, preset demand points are omitted at demand satisfaction constraint. This constraint line item also holds additional information such as ship-to-party, product and product type features of the underlying demand point. As a restriction, total volume of demand point must be replenished by a single plant. Since underlying sales volume cannot be distributed over multiple plants, Network Optimization solutions evolves towards an *integer programming* (IP) characterized mathematical model.

Capacity constraints reflect the rationale of scarce production source of production facilities. These constraints can be designated at four distinct detail levels: plant, product type (bag/bulk) and plant, product segment and plant, and lastly product and plant via the capacity planning steps introduced in Section 3.2.1. Additionally, sales volumes of preset typed demand points are subtracted from the corresponding capacity figures before network optimization run.

At optimization step, linear programming algorithm is applied to achieve profit maximization and solve the underlying assignment problem. This algorithm retrieves all simulated type demand point:plant combinations as candidate solutions and takes production capacity and demand satisfaction constraints into account. After data pre-processing step, the input data calculated at SAP BW system layer for the underlying version is transferred to optimization logic layer as shown in Figure 2.

Respectively, optimization step aims to maximize total objective function value, i.e. contribution margin or net profit. In this aspect, assignment of a demand point dp_i to a plant plt_j implies the demand satisfaction for dp_i and a local increase at objective function value worth of the unit margin value realized by dp_i:plt_j assignment calculated at Network Optimization data pre-processing step. On the contrary, a portion of capacity figures related to demand point dp_i and plant plt_j is diminished due to this demand satisfaction.

Technically, we positioned an integer programming characterized mathematical model to satisfy each demand point with exactly one plant in an optimality fashion such that, it maximizes total contribution margin or net profit with respect to any given number of plants and demand points.

Accordingly, `lpSolve` package has several input arguments to work appropriately such as objective function vector that is essentially the target for our problem required to be expressed in a mathematical way, and a constraint matrix to consider the constraints given above and totally satisfy them correctly. The constraint matrix is composed of two partitions: the demand constraint determined for each simulated typed demand point and capacity constraints planned at any detail levels. Finally, for every constraint we shall have an operand vector to express the limits in a mathematical manner, e.g., = or ≤ etc., and the constraint figures that can be considered as right-hand side (RHS) vector that holds the threshold values about the underlying constraints. After the completion of every aspect of the constraint side, optimization step is ready to use `lpSolve` functions, e.g. LP, to obtain the optimal results according to the input objective function coefficients and constraints.

Once mathematical model returns the global optimal solution vector, we convert the demand point:plant optimal assignments to a 2D matrix and traverse at this matrix to obtain 1-valued assignments with disregarding 0-valued elements. Finally, these assignments are transferred to SAP BW system layer for network optimization valuation step as shown in Figure 2. Additionally, underlying input data, i.e. objective function coefficients, demand satisfaction and capacity constraints, and optimal solution are also saved as local files at SAP file directory, aka AL11 transaction.

The underlying mathematical model is given below as Algorithm 1.

Algorithm 1: Integer Programming (IP) Characterized Network Optimization Mathematical Model.

$$MAX \sum_{dpi} \sum_{pltj} coef_{dpi,pltj} \times i_{dpi,pltj}$$

$$s.t.:$$

$$\sum_{dpi} vol_{dpi} \times i_{dpi,pltj} \leq cpcty_{pltj} \; for \; \forall pltj \in PLT$$

$$\sum_{dpi} vol_{dpi} \times i_{dpi,pltj} \leq cpcty_{pltj,prd\_typk} \; if \; dpi.prd\_typ = prd\_typk$$

$$\sum_{dpi} vol_{dpi} \times i_{dpi,pltj} \leq cpcty_{pltj,prd\_segk} \; if \; dpi.prd\_seg = prd\_segk$$

$$\sum_{dpi} vol_{dpi} \times i_{dpi,pltj} \leq cpcty_{pltj,prdk} \; if \; dpi.prd = prdk$$

$$\sum_{pltj} i_{dpi,pltj} = 1 \; for \; \forall dpi \in DP$$

$$i_{dpi,pltj} \in \{0,1\}$$

Line 1 represents objective function such that, binary variable $i_{dpi,pltj}$ holds the underlying atomic $dp_i{:}plt_j$ assignment decision and variable $coef_{dpi,pltj}$ is unit contribution margin or net profit coefficient calculated at network optimization pre-processing step. Value of these coefficients are determined according to the objective function type preference of the underlying version. Lines 2-5 represent capacity constraints determined at different plant and product detail levels, i.e. plant, demand point product type ($dp_i.prd\_typ$), product segment ($dp_i.prd\_seg$) or product ($dp_i.prd$). Respectively, Line 6 holds the customer satisfaction determined for each simulated typed demand point. The last line enhances integer programming (IP) characteristic to the underlying mathematical model.

After obtaining the optimal demand point:plant assignment solution, valuation step calculates exact gross sales, transportation cost, fixed and variable production cost, contribution margin and net profit values for each demand point via Equations 2-5. According to the planning dimensions, e.g. ship-to-party, plant and product, and the features of these planning dimensions, e.g. city, city district, product group, it is possible to analyse the network optimization valuation by zoom-in/out functionality. These figures are managed by version and GUID (i.e. a unique runtime identifier as shown in Figure 3) at Network Optimization solution. Process owner can compare different versions and network optimization runs for the corresponding period by keep/change variance analysis report. Finally, valuation figures of the optimal network optimization run are transferred to the adhoc reporting phase or Microsoft Power BI layer as shown in Figure 2.

3.2.3 Adhoc Reporting

Adhoc reporting phase provides various reporting functionalities to analyse the valuation figures for each valid before or after simulation typed versions, perform keep/change variance analysis among the corresponding what-if scenarios and monitor capacity consumptions at different plant and product detail levels.

4 EXPERIMENTAL RESULTS

In the scope of pilot runs, Network Optimization solution is implemented at one of our instalment-based SAP clients operating in cement industry. This leading organization has 6 plant facilities located in Central Anatolia region in Turkey and replenishes bag or bulk typed cement products to approximately 500 potential or actual ship-to-parties spread over Ankara, Black Sea, Central and Eastern Anatolia regions. Current product portfolio consists of 11 product groups.

As the experimental analysis, we focus on two months that are relatively sales intensive and bottleneck periods, i.e. August 2020 and September 2020, respectively. These periods constitute of approximately 350 demand points and 5 active capacity constraints designated at different plant and product detail levels as stated in Section 3.2.2. Due to what-if scenario evaluation, we created 6 distinct planning versions such that, two before simulation typed versions with *yyyy_mm*_B0 notation, two after simulation typed versions with *yyyy_mm*_A1 notation that maximize contribution margin and two after simulation typed versions with *yyyy_mm*_A2 notation that maximize net profit. Experimental results can be evaluated within two variance analysis: before versus after and after versus after variance analysis.

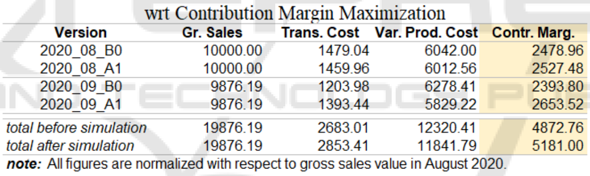
4.1 Before vs. After Variance Analysis

According to contribution margin maximization objective preference, Network Optimization solution promises adequate increase at the objective value by an average value of 6.33% as shown in Table 1. Although this improvement is degraded by the indispensable increase at transportation cost (approximately 6.35%), minimization of variable product cost by an average value of 3.88%, which constitutes the major portion of cost accrual, result in improvement at total contribution margin (from 4872.8K ₺ to 5181K ₺).

Similarly, net profit maximized network optimization increases the objective value by an average value of 26.9% as shown in Table 2. Although there happens a 9.73% increase at transportation cost, this tendency is damped by significant shrinkage at fixed and variable production costs, i.e. 4.04% and 6.04% reductions respectively.

The mechanism emphasized at both what-if scenarios is due to the fact that, while human insights at before simulation typed version is myopically based on transportation minimization, Network Optimization solution provides a wholistic perspective that considers both transportation and production cost drivers at profitability. Respectively, total (fixed and variable) production costs are approximately 4.9 times higher than total transportation costs. Hence, network optimization tends to assign demand points to geographically far

Table 1a: Before vs. After Variance Analysis.

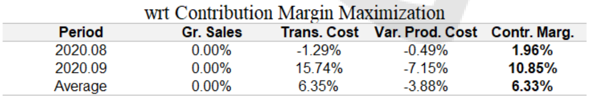


wrt Contribution Margin Maximization

Version	Gr. Sales	Trans. Cost	Var. Prod. Cost	Contr. Marg.
2020_08_B0	10000.00	1479.04	6042.00	2478.96
2020_08_A1	10000.00	1459.96	6012.56	2527.48
2020_09_B0	9876.19	1203.98	6278.41	2393.80
2020_09_A1	9876.19	1393.44	5829.22	2653.52
total before simulation	19876.19	2683.01	12320.41	4872.76
total after simulation	19876.19	2853.41	11841.79	5181.00

note: All figures are normalized with respect to gross sales value in August 2020.

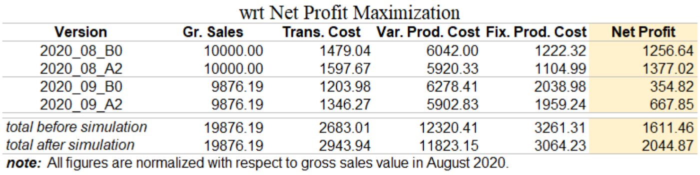
Table 1b: Nominal Variance per Period.



wrt Contribution Margin Maximization

Period	Gr. Sales	Trans. Cost	Var. Prod. Cost	Contr. Marg.
2020.08	0.00%	-1.29%	-0.49%	**1.96%**
2020.09	0.00%	15.74%	-7.15%	**10.85%**
Average	0.00%	6.35%	-3.88%	**6.33%**

Table 2a: Before vs. After Variance Analysis.

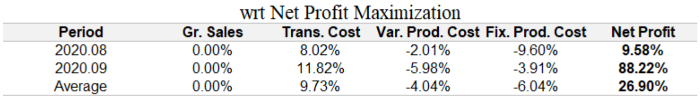


wrt Net Profit Maximization

Version	Gr. Sales	Trans. Cost	Var. Prod. Cost	Fix. Prod. Cost	Net Profit
2020_08_B0	10000.00	1479.04	6042.00	1222.32	1256.64
2020_08_A2	10000.00	1597.67	5920.33	1104.99	1377.02
2020_09_B0	9876.19	1203.98	6278.41	2038.98	354.82
2020_09_A2	9876.19	1346.27	5902.83	1959.24	667.85
total before simulation	19876.19	2683.01	12320.41	3261.31	1611.46
total after simulation	19876.19	2943.94	11823.15	3064.23	2044.87

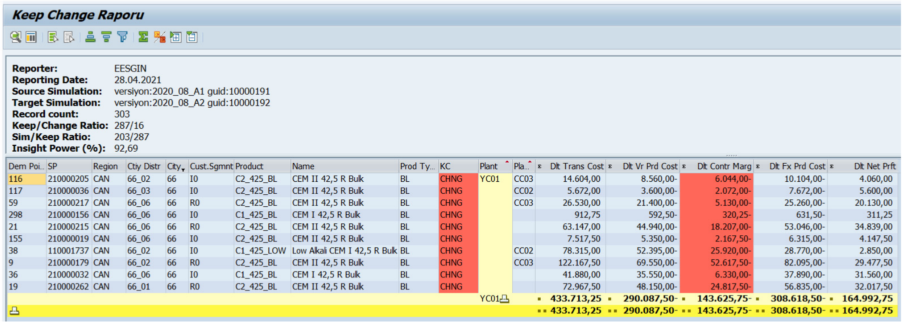
note: All figures are normalized with respect to gross sales value in August 2020.

Table 2b: Nominal Variance per Period.



wrt Net Profit Maximization

Period	Gr. Sales	Trans. Cost	Var. Prod. Cost	Fix. Prod. Cost	Net Profit
2020.08	0.00%	8.02%	-2.01%	-9.60%	**9.58%**
2020.09	0.00%	11.82%	-5.98%	-3.91%	**88.22%**
Average	0.00%	9.73%	-4.04%	-6.04%	**26.90%**



Keep Change Raporu

Reporter: EESGIN
Reporting Date: 28.04.2021
Source Simulation: versiyon:2020_08_A1 guid:10000191
Target Simulation: versiyon:2020_08_A2 guid:10000192
Record count: 303
Keep/Change Ratio: 287/16
Sim/Keep Ratio: 203/287
Insight Power (%): 92,69

Dem Poi...	SP	Region	Ctiy Distr	City	Cust.Sgmnt	Product	Name	Prod Ty...	KC	Plant	Pla...	Dlt Trans Cost	Dlt Vr Prd Cost	Dlt Contr Marg	Dlt Fx Prd Cost	Dlt Net Prft
116	210000205	CAN	66_02	66	I0	C2_425_BL	CEM II 42,5 R Bulk	BL	CHNG	YC01	CC03	14.604,00	8.560,00-	6.044,00-	10.104,00-	4.060,00
117	210000036	CAN	66_03	66	I0	C2_425_BL	CEM II 42,5 R Bulk	BL	CHNG		CC02	5.672,00	3.600,00-	2.072,00-	7.672,00-	5.600,00
59	210000217	CAN	66_06	66	R0	C2_425_BL	CEM II 42,5 R Bulk	BL	CHNG		CC03	26.530,00	21.400,00-	5.130,00-	25.260,00-	20.130,00
298	210000156	CAN	66_06	66	I0	C1_425_BL	CEM I 42,5 R Bulk	BL	CHNG			912,75	592,50-	320,25-	631,50-	311,25
21	210000215	CAN	66_06	66	R0	C2_425_BL	CEM II 42,5 R Bulk	BL	CHNG			63.147,00	44.940,00-	18.207,00-	53.046,00-	34.839,00
155	210000019	CAN	66_06	66	I0	C2_425_BL	CEM II 42,5 R Bulk	BL	CHNG			7.517,50	5.350,00-	2.167,50-	6.315,00-	4.147,50
38	110001737	CAN	66_02	66	I0	C1_425_LOW	Low Alkali CEM I 42,5 R Bulk	BL	CHNG		CC02	78.315,00	52.395,00-	25.920,00-	28.770,00-	2.850,00
9	210000179	CAN	66_02	66	R0	C2_425_BL	CEM II 42,5 R Bulk	BL	CHNG		CC03	122.167,50	69.550,00-	52.617,50-	82.095,00-	29.477,50
36	210000032	CAN	66_06	66	I0	C1_425_BL	CEM I 42,5 R Bulk	BL	CHNG			41.880,00	35.550,00-	6.330,00-	37.890,00-	31.560,00
19	210000262	CAN	66_01	66	R0	C2_425_BL	CEM II 42,5 R Bulk	BL	CHNG			72.967,50	48.150,00-	24.817,50-	56.835,00-	32.017,50
										YC01		**433.713,25**	**290.087,50-**	**143.625,75-**	**308.618,50-**	**164.992,75**
												433.713,25	**290.087,50-**	**143.625,75-**	**308.618,50-**	**164.992,75**

Figure 4: Keep Change Report for August 2020 period (variance analysis between 2020_08_A1 and 2020_08_A2).

and still feasible plants with high-tech production lines. This high-tech notion implies lower amortization costs, shorter standard production cycle times and higher capacity utilizations.

4.2 After vs. After Variance Analysis

As stated in Section 3.2.2, Network Optimization solution has a configurable objective function feature. Hence, it is possible to perform keep change variance analysis that emphasizes changing demand point:plant assignments due to the effect of contribution margin or net profit objective function preference.

In this aspect, there happens interesting demand point:plant assignment changes in August 2020 period as shown in Figure 4. 11 demand points in city 66 are priorly assigned to plant YC01, which is also located in city 66, at version 2020_08_A1. These demand points are then assigned to geographically far plants (e.g. CC02 and CC03) at version 2020_08_A2. According to these changing points, there raises an opportunity cost of 433.7K ₺ in transportation cost and 143.6K ₺ loss in contribution margin.

On the contrary, because of net profit maximizing objective function preference at version 2020_08_A2, it can evaluate further trade-offs potentially emerged between transportation cost and fixed production cost drivers such that, 143.6K ₺ loss at contribution margin is amended by 308.6K ₺ gain at fixed production cost. Due to the rationale of sunk costs realized by production idle capacity in plant YC01, i.e. higher amortization cost, longer standard production cycle times and lower capacity utilization, replenishment of cement to the underlying 11 demand points from geographically nearest plant turns into an unprofitable status.

As the non-functional business requirement, Network Optimization solution eliminates time-consuming and erroneous hand simulation performed by process owners at Microsoft Excel solver. Accordingly, current total processing time is dramatically lessened from 2 hours to 30 seconds at the pilot runs.

5 CONCLUSIONS

This paper demonstrates Network Optimization solution deployed at SAP system and proposed solution architecture provides a seamless network optimization experience over a large environment orchestrating SAP system, optimization logic and Microsoft Power BI layers. Correspondingly, the underlying solution paradigm aims to find global optimum demand point:plant assignments at product replenishment that maximize total profitability in terms of contribution margin or net profit with respect to sales, transportation and production planning data and concerning capacity and customer satisfaction constraints.

As the current (as-is) situation, human judgments is the major determinant in demand point:plant assignments within a myopic aspect solely focusing on transportation minimization. Additionally, hand simulation executed at Microsoft Excel solver is a time consuming and error-prone procedure such that, less effort is dedicated to more value adding operations. On the contrary, Network Optimization solution provides a wholistic aspect towards profit maximization by the leverage effect of mathematical modelling. Hence, process can focus on variance analysis and different what-if scenarios evaluation.

According to experimental results, Network Optimization solution increases the contribution margin by an average value of 6.33% and net profit by 26.9%. Additionally, configurable objective function feature at version management provides an effective after versus after variance analysis that compares different what-if scenarios highlighting potential trade-offs between transportation and production cost drivers. As the future work, we plan to spread proposed solution towards different industries confronting similar network optimization bottlenecks.

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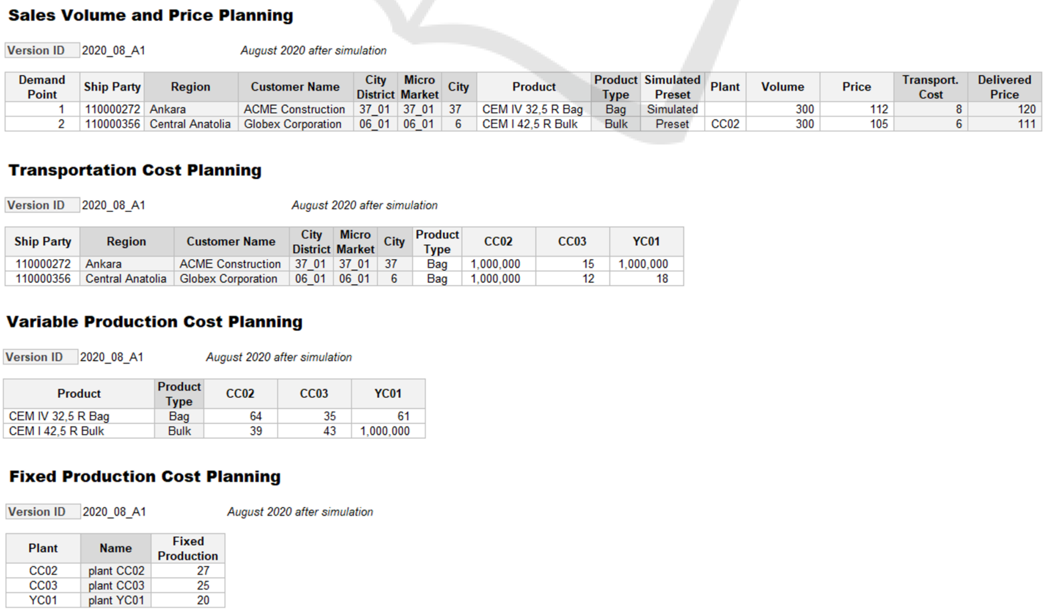
APPENDIX

Sample planning user interfaces, e.g. sales volume and price, transportation cost, variable and fixed product cost planning, are given in Figure 5.



Sales Volume and Price Planning

Version ID 2020_08_A1 *August 2020 after simulation*

Demand Point	Ship Party	Region	Customer Name	City District	Micro Market	City	Product	Product Type	Simulated Preset	Plant	Volume	Price	Transport. Cost	Delivered Price
1	110000272	Ankara	ACME Construction	37_01	37_01	37	CEM IV 32,5 R Bag	Bag	Simulated		300	112	8	120
2	110000356	Central Anatolia	Globex Corporation	06_01	06_01	6	CEM I 42,5 R Bulk	Bulk	Preset	CC02	300	105	6	111

Transportation Cost Planning

Version ID 2020_08_A1 *August 2020 after simulation*

Ship Party	Region	Customer Name	City District	Micro Market	City	Product Type	CC02	CC03	YC01
110000272	Ankara	ACME Construction	37_01	37_01	37	Bag	1,000,000	15	1,000,000
110000356	Central Anatolia	Globex Corporation	06_01	06_01	6	Bag	1,000,000	12	18

Variable Production Cost Planning

Version ID 2020_08_A1 *August 2020 after simulation*

Product	Product Type	CC02	CC03	YC01
CEM IV 32,5 R Bag	Bag	64	35	61
CEM I 42,5 R Bulk	Bulk	39	43	1,000,000

Fixed Production Cost Planning

Version ID 2020_08_A1 *August 2020 after simulation*

Plant	Name	Fixed Production
CC02	plant CC02	27
CC03	plant CC03	25
YC01	plant YC01	20

Figure 5: Sample Planning User Interfaces maintained via a version ID parameter. While editable fields are shown in light grey shade, the fields automatically extracted from planning dimensions' master data are given in dark gray color.