ISSN 2229-5518

PERFORMANCE ANALYSIS OF MULTICHANNEL PRODUCTION SYSTEM (CASE STUDY OF SOME COMPANIES IN NIGERIA)

Okehie, Ngozi and Okoli, John

1. ngozaioby@yahoo.com
2. john.okoli@uniport.edu.ng

Department of Mechanical Engineering, University of Port Harcourt, Rivers State Nigeria

Abstract

This paper presents the performance indices of multi-channel conveyor systems used at two major bottling companies located in the Northern and Southern parts of Nigeria. Questionnaire was used to collect the system and failure data. Analysis of the data showed that, the performance indices of the multi-channel conveyor system in the Northern part of Nigeria were as follows: Mean time between failures (MTBF) was 30.17hrs; the failure rate was 0.033 and the production efficiency was 90%. The reliability of the system improved from 34% to 82% when identified few failures at the various stations on the production line were eliminated which may eventually bring down cost of maintaining the system. The performance indices of the multi-channel conveyor system in the South were obtained as follows: Mean time between failures (MTBF) was 52.21 hours; the failure rate was 0.019 and the production efficiency was 83%. The reliability of the system improved from 32% to 80% when identified few failures at the various stations on the production line were eliminated which may eventually bring down cost of maintaining the system.

Key words; *Performance indices, Artificial intelligence, Mean Time Between Failures (MTBF) and production efficiency.*

CHAPTER ONE

1 Introduction

A conveyor belt system usually comes with a single belt. However, activities such as filling, capping, product separation or rejection etc, has necessitated a conveyor belt system having multiple belts running simultaneously; this is called multi-channel conveyor system.

The performance of a conveyor system declines overtime because of so many factors such as, age, poor maintenance, quality of spare parts etc.

To measure performance of a system bottlenecks of the production line are identified so as to enable the maintenance engineer carry out proper maintenance.

Performance analysis strengthens accountability, enhances decision-making, improves customer service, assists management in determining effective resource use, supports strategic planning and goal-setting, provides early detection of problems, and it can potentially enhance the production rating (Viswanadham and Narahari 2011).

Two major multi-national bottling companies in the Northern and Southern parts of Nigeria were investigated for performance output. They run 24-hours production time except there is a breakdown.

2 MATERIALS AND METHOD

2.1 Basic Multi channel Production System information

Company A located in the Northern part of Nigeria and company B located in the Southern part of Nigeria has eight and five stations respectively as shown in fig 1a and 1b respectively.

2.2 Production line layout of company A

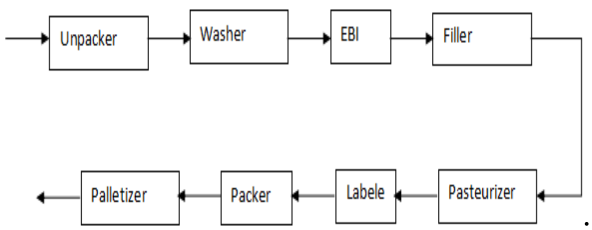

Figure 1a: Production line layout of Company A

Figure 1a shows production line layout of Company A. The bottles go through the following eight production steps:

At the unpacker, bottles are transferred from pallets to the first conveyor belt, which moves the bottles to the next station the washer.

At the washer, bottles are thoroughly washed. The bottles move to the next station via a conveyor belt.

At the EBI the bottles are inspected bottles with particles or broken bottles are rejected

Next, the bottles move to the filler

At the filler the bottles are filled with the liquid to the specified capacity. It then moves to the next station, the pasteurizer

At pasteurizer, the bottles are heated and then cooled for conservation purposes.

The labeler provides the bottles with the correct labels.

In the packer, the bottles are either packed into six-packs or into crates.

Lastly, the palletizer puts the crates or six packs on pallets, after which they can be transported to customers.

2.3 Production line layout of Company B

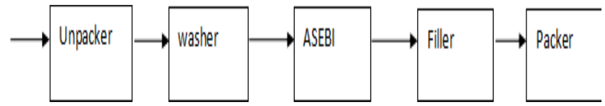

Figure 1b: Production line layout of Company B

Figure 1b shows production line layout of Company B. The bottles go through the following five production steps:

At the unpacker station the bottles are transferred from the pallet to the conveyor. The bottles move to the washer station where they are thoroughly washed. After being washed they move to the ASEBI (All Sensor Electronic Bottle Inspector), where the bottles are inspected. At this point faulty bottles are rejected and pushed out of the production line. The bottles move to the filler where they are filled with the liquid. The filled bottles move to the next production line where the process will be completed.

2.4 Operation of production line

The machines in both production lines are in series connection. Therefore failure of any of the machines would cause failure in the entire production line.

3 Materials and method

A questionnaire was used to collect time series of failure for each of the production lines. The following were the basic questions asked.

Multi-channel conveyor characteristics
Level of artificial intelligence
Load on conveyor
Time and position of product along conveyor.
Daily production.
Time of failure of machines in the system

To measure the performance of the system the following performance parameters of the various machines at the stations are measured.

3.1 Reliability Analysis

O'Connor', (2002) states that Pareto principle is the first step to reliability and data analysis. Therefore, this principle

ISSN 2229-5518

shall be used to analyze and also calculate the reliability of the various machines at the work stations.

Reliability: This is the probability that the entire line (workstations or machines) will perform a required function under stated operating conditions for a period of time (t)

Mathematically

$R(t)=1-F(t)$ (3.1)

Where F(t) is the probability of failure

Reliability can also be calculated using

$R(t) = e^{-\lambda t}$ (3.2)

Where;

R(t) = reliability estimated for a period of time.

λ = failure rate

Reliability of system in series is the product of all the reliability of the machines that made up the system.

$R_{system}=R_1 x R_2 x R_3 \ldots\ldots\ldots\ldots\ldots\ldots R_n$ (3.3)

3.2 $\text{Failure Rate} = \frac{r}{t}$ (3.4)

Where:

r =Number of failures occurring during investigation.

t = Total running time during investigation.

From equation 3.1

$F(t)=1-R(t)$ (3.5)

The hazard function

$H(t)=-\ln[1-F(t)]$ (3.6)

Equation 3.5 is the exponential distribution of time to failure.

It follows that:

$H(t)=\lambda t$ (3.7)

And

$t(H)=1/\lambda$ (3.8)

Therefore, time to failure is a linear function of the cumulative hazard. The line passes through the origin and its slope 1/λ is the mean time before failure.

3.3 Mean time before failure (MTBF) is the reciprocal of the failure rate. That is,

$\text{MTBF} (\mu) = \frac{t}{r}$ (3.9)

Where,μ= Mean time before failure

t = total running time

r = no of failures

$\mu_{system}=1/\lambda_{system}$ (3.10)

The most important performance measure is the production efficiency which is the throughput of production line divided by the line rated speed (Jacobus Johannes 2012).

3.4 Production efficiency = $\frac{Q/T}{L}$ (3.11)

Where Q = the total quantity of bottles produced

T= the actual production time

L= is the line rated speed (speed of the filler)

4 RESULTS AND DISCUSION

4.1 Performance indices of multichannel conveyor system of company A

Table 1 Shows the failures that occurred at the various stations arranged in descending order. The probability

ISSN 2229-5518

of failure F(t), the cumulative frequency of failure and reliabilities R(t) of the various machines were calculated. Hence the reliability of the system was deduced.

Table 1: Failure of machines of company A

Machine	No of failures	R.FEQ	R.FEQ %	C.FEQ	R
Filler	29	0.28	28	28	0.72
Pasteurizer	14	0.13	13	41	0.87
Labeller	14	0.13	13	54	0.87
EBI	13	0.12	12	66	0.88
Washing machine	11	0.1	10	76	0.9
Depacker	9	0.09	9	85	0.91
Palletizer	9	0.09	9	94	0.91
Packer	6	0.06	6	100	0.94
Total	105	1	100		0.335975

A total of 105 failure cases were recorded, hence the relative frequency for filler is = 0.28

And the reliability of the filler R_1 is = 0.72

The reliability of the system is:

Rs(t) = 0.34

Therefore, Unreliability = 0.66

The Pareto chat was plotted based on the data of table 1. The line plot and graph represent the cumulative failure frequency curve and frequency of failure respectively.

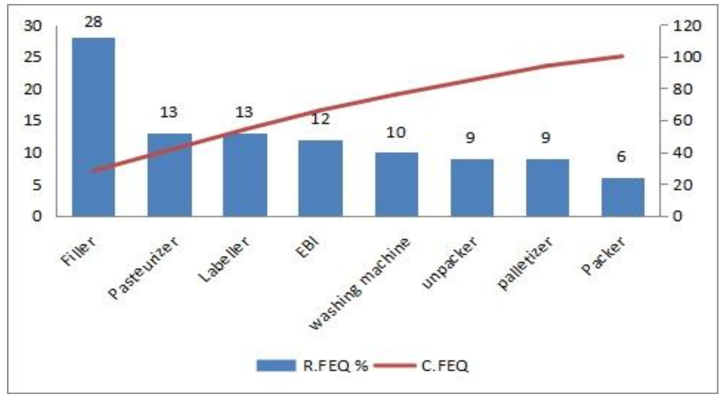

Figure 2: Pareto Chart of machine Failure Data of company A

The filler, pasteurizer, labeler, EBI and the washing machine are the obvious few failures that need to be attended to. Fixing these failures will lead to failure reduction in the production system.

The improvement due to the application of Pareto analysis is the product of the percentage of failure that requires attention and unreliability. This is equal to 0.48

Thus, attending to the filler, Pasteurizer, labeler and EBI will lead to unreliability reduction of 0.48. This fraction reduction of unreliability will lead to the same fractional increase in reliability, thus the reliability becomes: 0.82.

Failure frequency can be approximated to an exponential distribution as shown in figure 3.

ISSN 2229-5518

Figure 3: Relative frequency of machine failure of company A

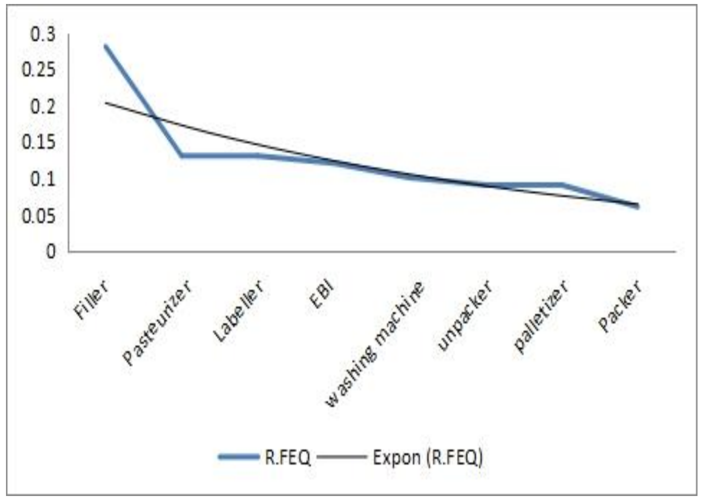

Figure 3 above shows that the failure frequency can be approximated to an exponential distribution. Hence knowing the failure distribution λ the failure rate can be determined from the hazard function.

Table 2. shows the hazard calculation for failure time of company A.

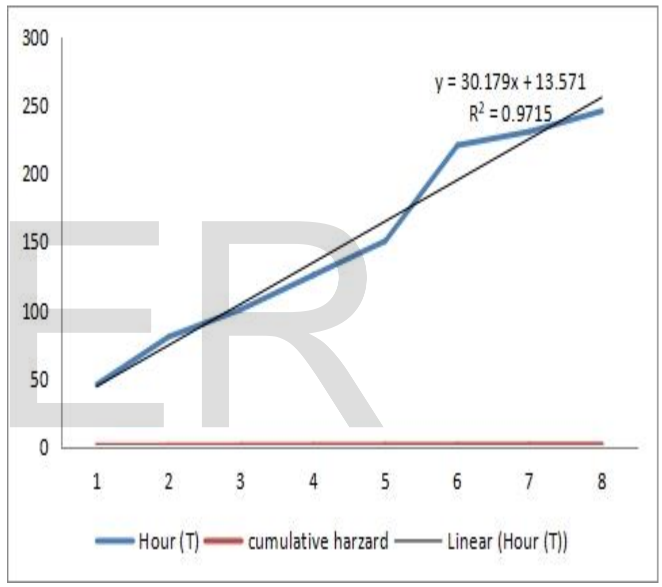

Figure 4 Hazard function graph of company A

Table 2 **Hazard Calculation For Failure Time**

Hour (T)	R	Hazard	cumulative hazard
40	0.72	0.328504	0.33
80	0.87	0.139262	0.47
100	0.87	0.139262	0.61
125	0.88	0.127833	0.74
150	0.9	0.105361	0.85
220	0.91	0.094311	0.94
230	0.91	0.094311	1.03
245	0.94	0.061875	1.09

The data from table 2 was used to plot the hazard function graph. It is a line plot of the cumulative hazard against the failure time as shown in figure 3

The line graph approximates the hazard function. The slope is 30.17 hours this implies that the mean time between failure μ of the system is 30.17 hours, hence the failure rate λ is 0.033/hour. The intercept 13.57 hours indicates the failure free life.

The performance of the various machines that made up the production line is the major factor that affects the performance of the entire production line.

Table 3 shows the summary of the performance indices of the various machines on the production line.

Machines	**Depacker**	**washing m/c**	**EBI**	**Filler**	**Pasturizer**	**Labeller**	**Packer**	**Palletizer**
Failure Rate/1296 hr	0.007	0.008	0.01	0.022	0.011	0.011	0.005	0.007
Reliability	0.91	0.90	0.88	0.75	0.87	0.87	0.94	0.91
No. of Breakdown	9	11	13	29	14	14	6	9
MTBF	142.86	125	100	45.45	90.9	90.9	200	142.86

Table 3 Summary of performance indices of various multi-channel conveyors system company A

The summary of analysis carried out on the data collected from company A is shown in table 4.12. This reveals the performance indices of the seven channel conveyor system used in the factory. From the result of the analysis, the filler has the highest failure rate of 0.022/1296hrs and the packer has the lowest failure rate of 0.005/1296hrs. The packer is the most reliable, while filler is the most unreliable of the seven stations. The filler station had the lowest mean time between failures of 45.45 hrs while the packer has the highest mean time between failures of 200hrs.

Failure rate of the system = 0.033

MTBF of the system is = 30.17hours

When the repairs are done the reliability of the system increases from 0.34 to 0.82

4.2 Production efficiency

The maximum, minimum and average daily production of soft drinks is 42,000 bottles, 22,100 bottles and 32,575 bottles respectively.

The Production efficiency = 90%

Daily quantity of drinks produced is represented in Figure 5.

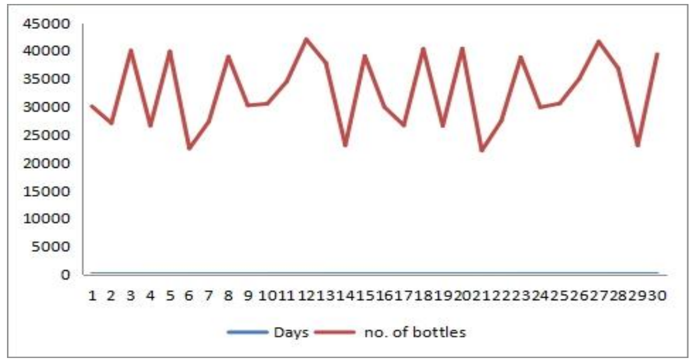

Figure 5: Daily production quantity of company A

The quantity of drinks produced each day varies as a result of breakdown.

4.3 Performance indices of multichannel conveyor system of company B

Table 4 Failure of Machines in company B arranged in descending order of relative and cumulative frequencies

A total of 40 failure cases were recorded, hence the relative frequency for filler is = 0.3

And the reliability R_1 of the filler is = 0.7

The reliability of the system is:

$Rs(t) = 0.32$

Therefore, Unreliability = 0.68.

The data in table 6 was used to plot the Pareto chart. The line plot and bar graph represent the cumulative failure frequency curve and frequency of failure respectively.

Figure 6: Pareto Chart of machine Failure Data of company B

The change because of the use of Pareto examination is the result of the product of failure that requires consideration and unreliability, this is equivalent to 0.48.

Thus, attending to the filler, Pasteurizer, labeler and EBI will lead to unreliability reduction of 0.48. This fraction reduction of unreliability will lead to the same fractional increase in reliability, thus the reliability becomes 0.80.

Machine	No of failures	R.FEQ	R.FEQ%	C.FEQ	R
Filler	12	0.3	30	30	0.7
ASEBI	10	0.25	25	55	0.75
Washer	7	0.175	17.5	72.5	0.825
Unpacker	6	0.15	15	87.5	0.85
Packer	5	0.125	12.5	100	0.875
					0.322
	40	1	100		

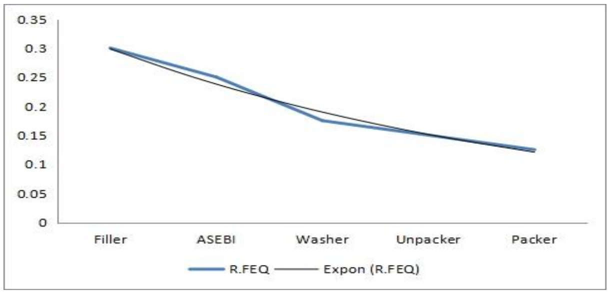

Figure 7: Relative frequency of machine failure of company

Figure 7 demonstrates that the disappointment recurrence can be approximated to an exponential conveyance. Thus knowing the disappointment circulation λ the disappointment rate can be resolved from the danger capacity.

Table 5 Hazard calculation for failure time

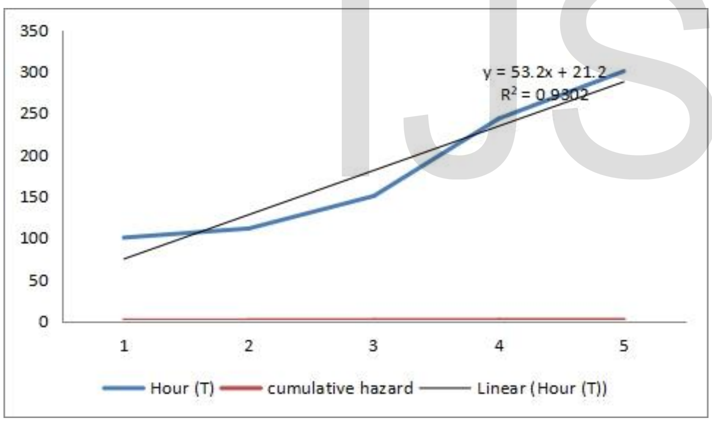

Table 6: Summary of performance indices of various machines on the multichannel conveyor system of company B

Figure 8 Hazard function graph

The data in table 5 above was used the plot a graph of the cumulative hazard against the failure time as shown in figure 8

Hour (T)	R	Hazard	cumulative hazard
100	0.7	0.356675	0.36
111	0.75	0.287682	0.69
150	0.825	0.192372	0.84
243	0.85	0.162519	1
300	0.875	0.133531	1.13

The line graph approximates the hazard function. The slope is 53.21 hours this implies that the mean time between failure μ of the system is 53.21 hours; hence the failure rate λ is 0.019/hour. The intercept 21.2 hours indicates the failure free life.

The summary analysis of the data collected from

Parameter/ Machines	Unpacker	Washer	ASEBI	Filler	Packer
Failure rate	0.005	0.005	0.008	0.009	0.004
Reliability	0.85	0.825	0.75	0.7	0.875
No of breakdown	6	7	10	12	5
MTBF	200	200	125	111.11	250

company B shows that the filler station has the highest failure rate of 0.009 and the packer has the lowest failure rate. This accounts for the reason why some of the bottles are not filled to the right capacity. The most reliable system is the packer station. Filler station has the lowest mean time before failure (MTBF) of 111.11hrs. This means that at every 111.11hrs of operation there is failure which occurs on the production line. The maximum MTBF value is 250hrs which occurred at packer station.

Failure rate of the system = 0.019

MTBF of the system is = 53.21hours

Reliability of the system = 0.80

(When the repairs are done the reliability of the system increases from 0.32 to 0.80)

4.4 Production Efficiency

The maximum and minimum monthly productions are 31,384 and 19,285 respectively and an average production of 25,000. The line rated speed is 1250bottles/hour. Therefore, the Production efficiency = 83%. The daily production is represented in Fig 4.5

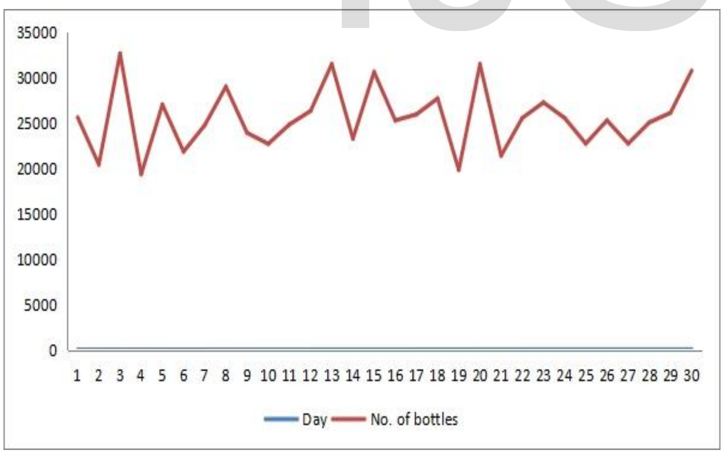

Figure 9 Daily production quantity of company B

The quantity of drinks produced varies for different days. This is as a result of downtimes especially the unplanned ones

5.1 Conclusion

The following performance indices were obtained for company A located in the Northern part of Nigeria: The filler has the highest failure rate of 0.022 and the packer has the lowest failure rate of 0.005. The packer is the most reliable, while filler is the most unreliable of the seven stations. The filler station had the lowest mean time between failures of 45.45 hrs. This means that at every 45.45hrs of operation, failure occurred at the filler station on the production line. The packer had the highest mean time between failures of 200hrs. Hence the systems MTBF, failure rate, and production efficiency were 30.17hrs, 0.033, 90% respectively. The reliability of the system was calculated to be 0.34, elimination of identified few failures at the various stations resulted to reliability increase of 0.82.

The following performance indices were obtained for company B located in the Southern part of Nigeria: The filler station had the highest failure rate of 0.009 and the packer station had the lowest failure rate of 0.004. The packer is the most reliable, while filler is the most unreliable of the five stations. The filler station had the lowest mean time before failure (MTBF) of 111.11hrs. This means that at every 111.11hrs of operation, failure occurred at the filler station on the production line. The maximum MTBF value was 250hrs, which occurred at the packer station. Hence the systems MTBF, failure rate, and production efficiency were 53.71hrs, 0.019, 83% respectively. The reliability of the system was calculated to be 0.32, elimination of identified few failures in the various stations resulted to reliability increase of 0.80.

The maintenance staff should take note of this to avoid breakdown. In addition they should focus more on the conveyor lines. Buffers should be provided in order to cope with the unexpected failures of the machines which interrupt production process (Van Der Duyn, & Vanneste.(1995). At long last to make a nonstop stream more sensors and that can make diverse pace levels are essential at the distinctive stations of the generation line.

5.2 Recommendations

Further, research can be extended by developing a performance predictive model and improving the production lines of the companies used in this study.

At the moment operators choose when crates should be put on the conveyor and when it should be pulled from the conveyor. When an operator is busy on another machine he/she is not available at that time to regulate the crate conveyor. Further research should be carried out to indicate if it is profitable to make this automatic and how it should be done.

References

Abdulkareem, H.A., Mohammed, A.N, & Garba, M.A.(2014) : Analysis Of Failure Mode In Globe And Butterfly Valves: Case Study Nigerian Bottling Company PLC

O'Connor (2002). Chapter 15, Reliability management, Practical Reliability Engineering,

Blischke, W. R., & Murthy, D. N. P. (2003). Case studies in reliability and maintenance

(pp. 351–445). Hoboken, NJ: Wiley.

Gupta, S. & Bhattacharya, J. (2007).Reliability Analysis Of A Conveyor System Using Hybrid Data. Quality And Reliability Engineering International, 23, 867–882

Hajeeh, M. & Chaudhuri, D. (2000).Reliability And Availability Assessment of Reverse Osmosis Desalination, 130, 185–192.

John, Wiley (2012): Introduction to Reliability (Portsmouth Business School, April 2012)

Kardon, B. & Fredendall, D. L. (2002). Incorporating Overall Probability Of System Failure Into A Preventive Maintenance Model For A Serial System. Journal Of Quality In Maintenance Engineering, 8, 331–345.

Papadopoulos, Heavey & Browne (2011), "An Efficient Assembly line Balancing in Automobile Manufacturing", IEEE , vol.11, 2011

Viswanadham & Narahari., "Evaluating focused factory benefits with queuing theory", European Journal of Operational Research 128 , pp.

597-610, 2011