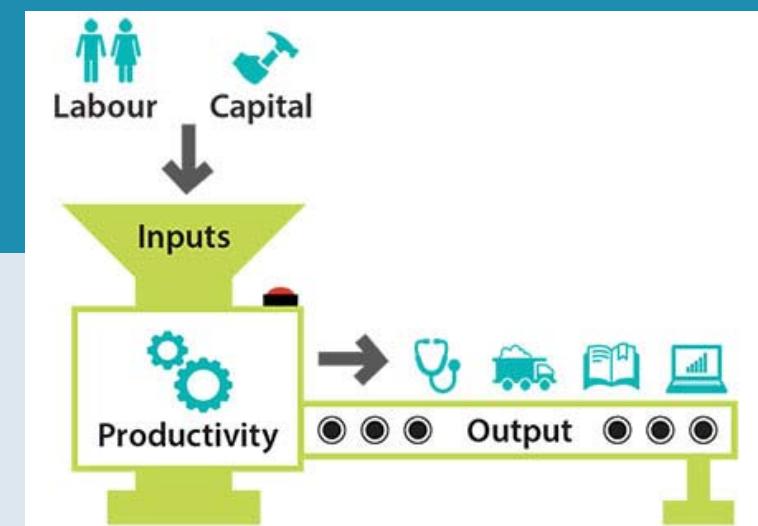


Productivity



Agenda

Basics

What is it about? Management issues for KPI's. What about data and what about reporting?

Special topics

Illustrated
(...)

To discuss



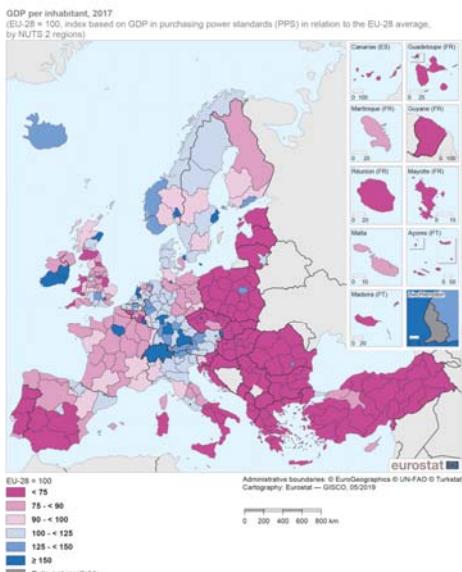
Basics



Exploring “productivity”, performance, ...



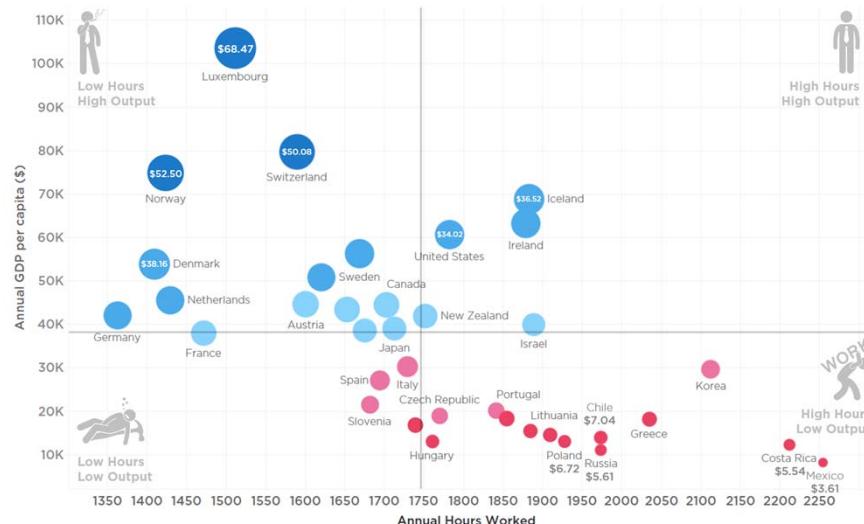
Many examples, ...



The World's Productivity 2017

Productivity Per Person Per Hour

> \$40 \$30 - \$39.99 \$20 - \$29.99 \$10 - \$19.99 \$0 - \$9.99



Productivity Per Person Per Hour (Selected 35 Countries)

Article and Sources

<https://howmuch.net/articles/worlds-most-productive-countries>
International Monetary Fund; Organisation for Economic Co-operation and Development

howMuch.net



Definition(s)

intuitively obvious, but scientifically fuzzy - no universal definition – customized for situation at hand

relationship between output of goods and services and the input of resources, human and non-human, used in the process

reaching the highest level of performance with the lowest possible expenditures

$$\text{Productivity} = \frac{\text{Units of output}}{\text{Units of input}}$$



Industry	Inputs	Outputs
Auto	Labor hours, machine hours	Number of cars produced
Steel	Furnace size	Tons of steel
Oil	Refinery size	Gallons of fuel
Farming	Number of acres	Bushels of grain
Restaurant	Tables, seating capacity	Number of meals served
Theatre	Seats available	Number of tickets sold
Retail	Square feet of floor space	Revenue generated

Basic formulas



$$\text{efficiency} = \frac{\text{theoretical input}}{\text{actual input}}$$

$$\text{effectiveness} = \frac{\text{actual output}}{\text{theoretical output}}$$

$$\text{productivity} = \frac{\text{output}}{\text{input}}$$

$$\text{productivity index} = \frac{\text{theoretical productivity}}{\text{actual productivity}}$$

Related aspects (performance)

(Productivity)

Effectiveness

Efficiency

Quality, Safety, Motivation,
Innovative power, Flexibility,
Profitability, Sustainability
and many more ...

Then (pre 1970s)

Industrial Revolution

Financial Measures

Tangible Assets

Lagging Indicators

(aka: outcome measures, historic measures)

Now (post 1970s)

Information Age

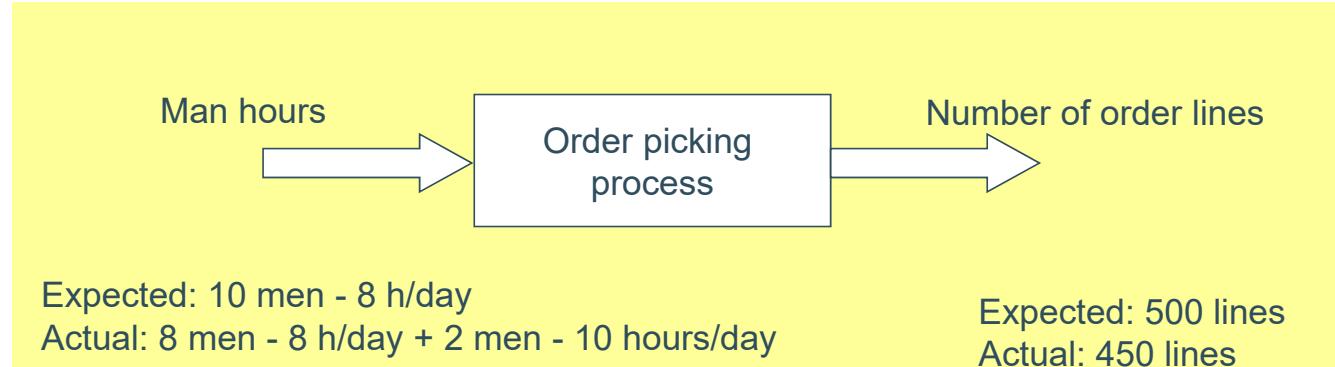
Financial plus non-financial Measures

Non-tangible assets (invisible assets)

Leading Indicators

(aka: performance drivers, predictive measures)

Exercise 1



Exercise 2

A company has launched a project in order to recall “bad” products. The goal is to attain a 90% return of the 300000 bad units sold. The budget for the project is \$2/unit returned.

Consider following scenarios:

Scenario 1: 250000 units returned - costs \$510000

Scenario 2: 280000 units returned - costs \$550000

Establish for both scenarios if they are efficient and/or effective.



Solution Exercise 1

Efficiency = $(8*10)/(8*8+2*10) *100\% = 95\%$

Effectiveness = $(450/500)*100\% = 90\%$

Productivity (actual) = $450/(8*8+2*10) = 5.36$

Productivity (theoretical) = $500/(10*8) = 6.25$

Productivity ratio = $5.36/6.25 *100\% = 86\%$

Note that e.g. efficiency could be larger than 100%

Solution Exercise 2

Scenario 1

Effective: NO, because $250000 < 270000$

Efficient: NO, because $510000/250000 > 2$,
although $510000 < 540000$

Scenario 2

Effective: YES, because $280000 > 270000$

Efficient: YES, because $550000/280000 < 2$,
although $550000 > 540000$

We can have - with these definitions - an efficiency and effectiveness of **more than 100%**. A **concise definition** is indispensable !!

Types of measures

Static measures

Dynamic measures

Surrogate measures

Leading/lagging measures

total
multi-factor/partial
single factor

example

business unit XYZ

output (\$) sales

input (\$) labor

investment

raw materials

contractor

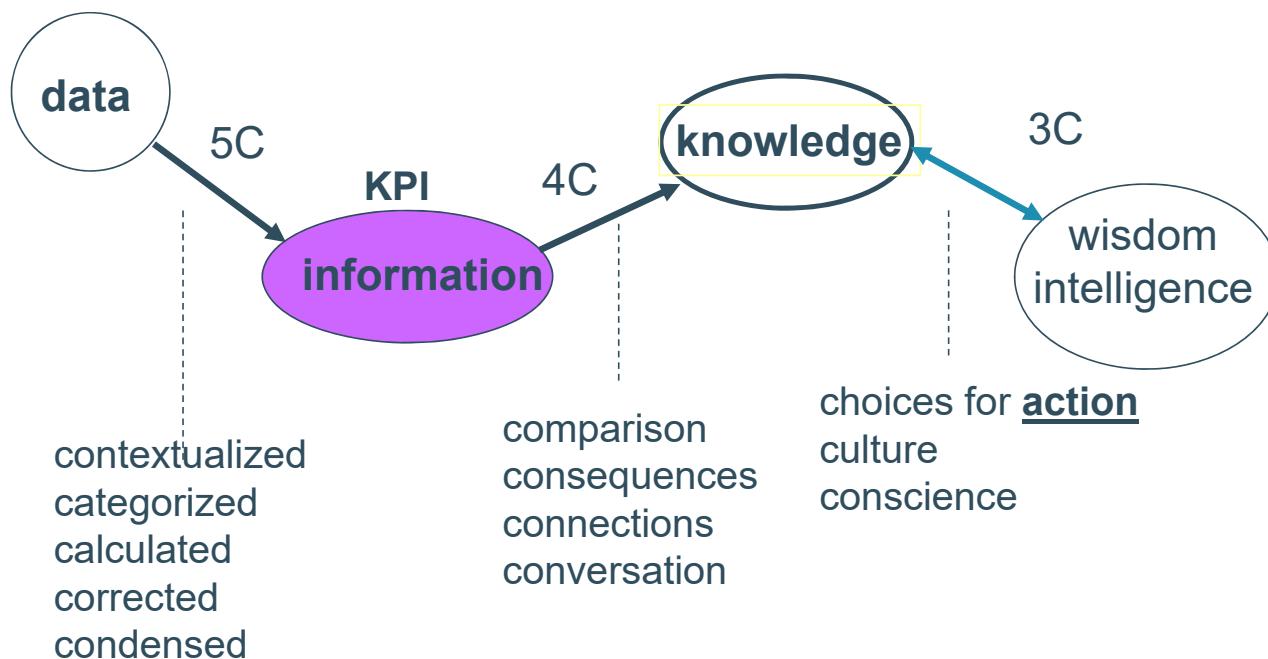
other



Data needed



DATA
MINING
RECOGNITION



Processing the data

Example

Picking orders in regional distribution centers



Which KPIs ? - Stuff to think about

The concept

"One accurate measurement is worth more than a thousand expert opinions."

- Admiral Grace Hopper,
USN

Alice: Would you tell me, please, which way I ought to go from here?
The Cat: That depends a good deal on **where you want to get to.**
Alice: I don't much care where.
The Cat: Then it doesn't much matter which way you go.
Alice: ... so long as I get somewhere.
The Cat: Oh, you're sure to do that, if only you walk long enough.
(Lewis Carroll, 1832-1989)



Most managers, rather than suffering from a lack of relevant information, suffer more from an **overabundance of irrelevant information**. It might be said that what managers need to know, they just cannot find it.
(Russell L. Ackoff, 1919-2009)

When you can **measure** what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced it to the stage of science.
(Sir William Thompson (Lord Kelvin), 1824-1907)

Management by numerical goal is often an attempt to manage without **knowledge of what to do.**
(W. Edwards Deming, 1900-1990)

Not everything that can be counted **counts**, and not everything that counts can be counted.
(Albert Einstein, 1879-1955)

People do what you **inspect**, not what you expect.
(Lou Gertsner, 1942-)

Criteria for KPI's

SMART

S: specific, stimulating, simple

M: measurable, motivating

A: achievable, agreed, attainable, assignable, appropriate, actionable

R: relevant, realistic, results/results-focused/results-oriented, resourced

T: timely, time-bound, time framed, timed, time-based, timeboxed, time-specific, timetabled, trackable

E: exciting, evaluated

R: recorded, rewarding, reviewed



Keep in mind:

Business context : what is important ? - Managerial levels have different needs – Set of KPIs must cover “all” important aspects

Specific: clear objectives – not “answer job requests fast”, but “reply to job requests within 24 h”

Measurable: can we (already) measure “it” in a reliable way ? – e.g. ERP or EAMS

Achievable: target not too high, not too low – e.g. # jobs/day

Agreed: all should agree on definition – e.g. service level

Relevant: (a) what is measured = what can be changed – e.g. MRO stock rotation (purchasing dept ?) – (b) important for the organization

Timely: as needed for mgmt purposes – e.g. report of April is due 1st of May

Time-bound: clear what period is covered, dated

Some metaphores

Brancusi
(white negresse II, 1928)
(marble, (stone, wood))



Imagine yourself as the designer for the control/instrument panel of a jetline. Think through some of the issues you would consider in terms of deciding:

developing a PI system
what PI's ?
on what level ?
relative PI importance
decision power & impact

How can we design a control system that does not overload the pilot ?

What control aspects can we automate ~~more~~ to relieve the pilot from routine decisions ?

An airplane has categories of performance measures: navigation, communication, engine performance, aircraft attitude, and (!) control response.



KPI examples

Illustration 1: APQC



Warehousing

Annual lines shipped per SKU
Cases per hour
Dock to stock cycle time
Inventory accuracy
Items on hand
Lines shipped per person hour
Pallets shipped per person hour
Percentage error in cases shipped
Percentage error in lines shipped
Percentage error in orders shipped
Picking error rate
Replacement costs for material handling and storage
Total person hours worked per year
Warehouse inventory (dollar value) as a percentage of sales dollars
Warehouse inventory (dollar value) as a percentage of total purchase dollars

Product delivery

Complaints of shipping damage
Distribution costs (transportation, warehousing, customer service, administration, inventory carrying)
Fill rate (speed of delivery)
Freight costs per parts shipment
Frequency of delivery to customers
Number of bill of loading errors not caught in shipping
Percentage incomplete delivery
Percentage misdelivery
Percentage of late shipments
Percentage of shipping errors
Percentage on time delivery (promised)
Percentage on time delivery (requested)
Ratio of actual deliveries to scheduled deliveries
Transportation cost per unit

Inventory management

Annual inventory turns
Annual work in process (WIP) turns
Back orders
Cost of stores
Gross inventory as a percentage of sales dollars
Inventory carrying cost
Inventory reliability: line items filled on first try per total line items ordered
Integrated supply contract
Inventory expenses
Item usage
Line items processed per employee/hour
On time delivery
Pilferage reduction
Reduced freight expenses
Vendor lead time
Stock turns per year

Illustration 2: MMH



Which issues are very important?			
Distribution, warehousing and manufacturing			
Issue	Very important, %	Retail rank	General industry rank
Cost containment	77	1	1
Company growth	68	2	5
Training	64	3	2
Throughput	62	4	4
Ergonomics and safety	57	5	3
Cycle times	51	6	6
Labor availability	46	7	7
Capital availability	40	8	8
Hours of service	33	9	9
Smaller, more frequent orders	27	10	10
Facility consolidation	26	11	11
Trading partner collaboration	24	12	12
Outsourcing	21	13	13

Which metrics are very important?			
Distribution, warehousing and manufacturing			
Practice	Very important, %	Retail rank	General industry rank
Shipping accuracy	92	1	1
Inventory accuracy	87	2	3
On-time shipping	86	3	2
Picking accuracy	86	3	4
Inventory levels	77	5	7
Daily throughput	69	6	6
On-the-job injuries	65	7	5
Order fulfillment costs	63	8	8
Labor hours	60	9	10
Order cycle times	59	10	9
Dock-to-stock time	42	11	12
Activity-based costing	35	12	11

Illustration 3 (revisited)

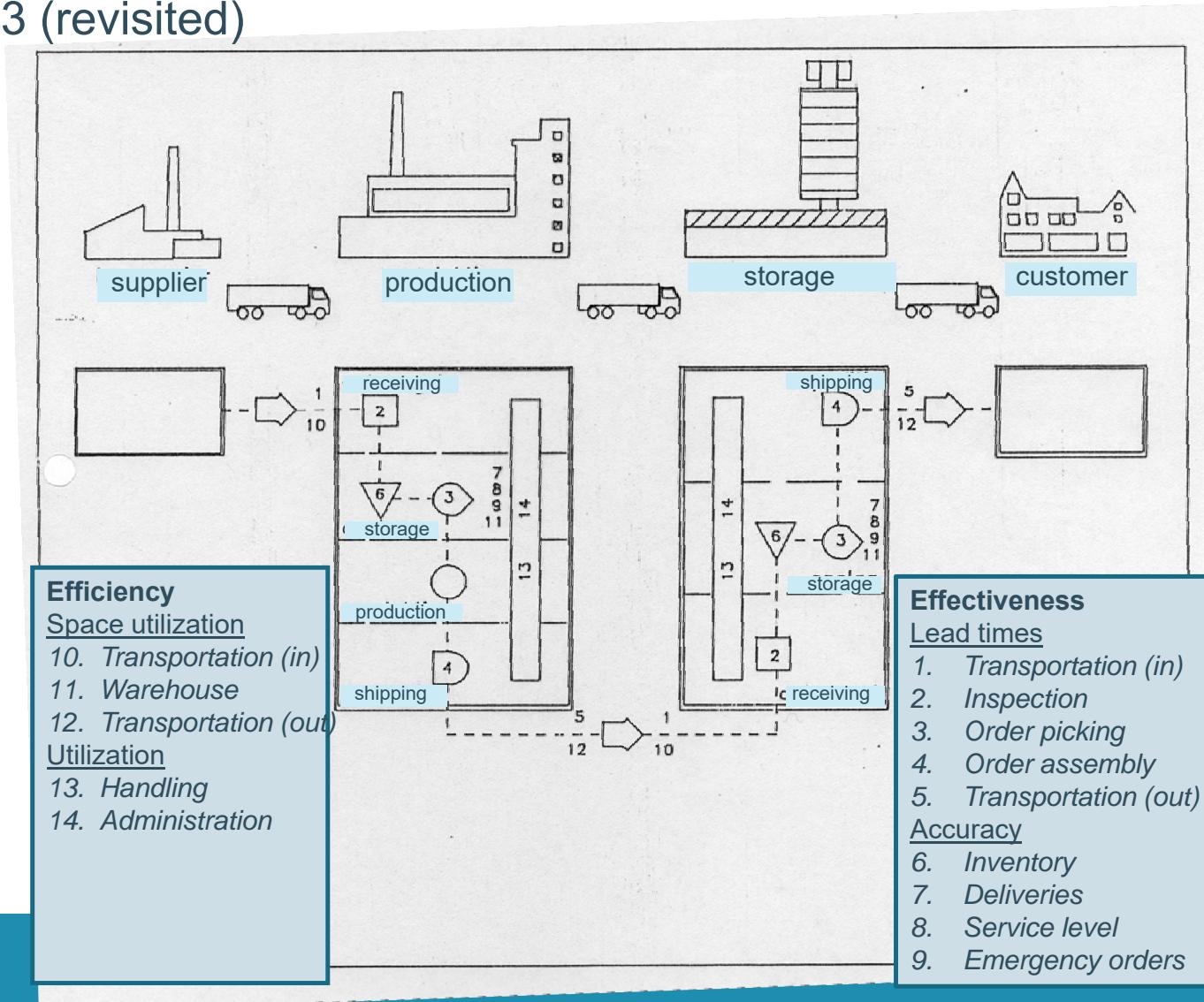


Illustration 4



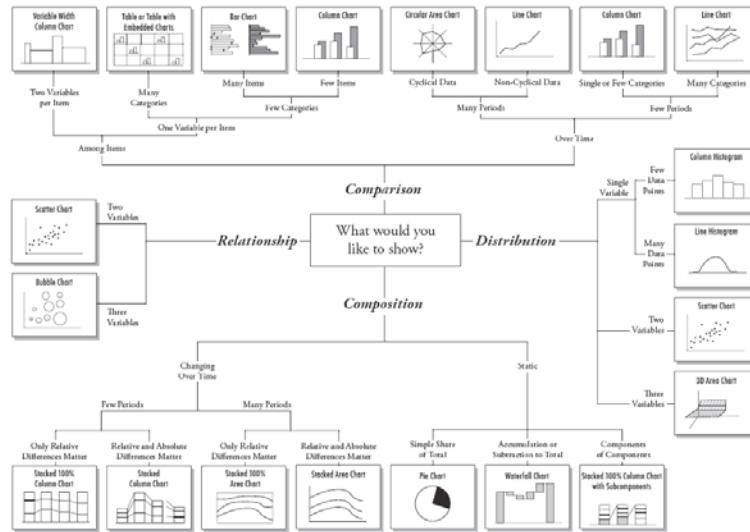
In order to capture customers' input in a meaningful and useful manner, Federal Express developed a system of Service Quality Indicators (SQIs). These indicators reflect the customers' views concerning their satisfaction with the performance of Federal Express. The list of SQIs is as follows:

1. Delivery on the right day but after the promised time
2. Delivery on the wrong day
3. Unsuccessful trace of a package
4. Customer complaints
5. Proof of performance is missing
6. Missed pickups from customers
7. Damaged packages
8. Lost packages
9. Unanswered calls from customers (not answered within 20 seconds)

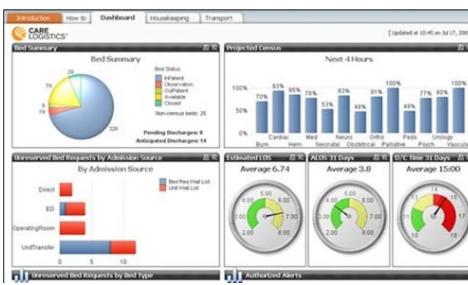
KPI reports

Graph or table?

If graph, which type?
(snap shot vs follow-up in time ?)



Dashboards



Special topics

Balanced scorecard (BSC)

(°: Kaplan & Norton - 1992)



Financial Perspective
measures the ultimate results that the business provides to its shareholders

Customer Perspective
focuses on customer needs and satisfaction as well as market share

Internal Perspective
focuses attention on the performance of the key internal processes which drive the business

Organizational Learning
directs attention to the basis of all future success - the organization's people and infrastructure

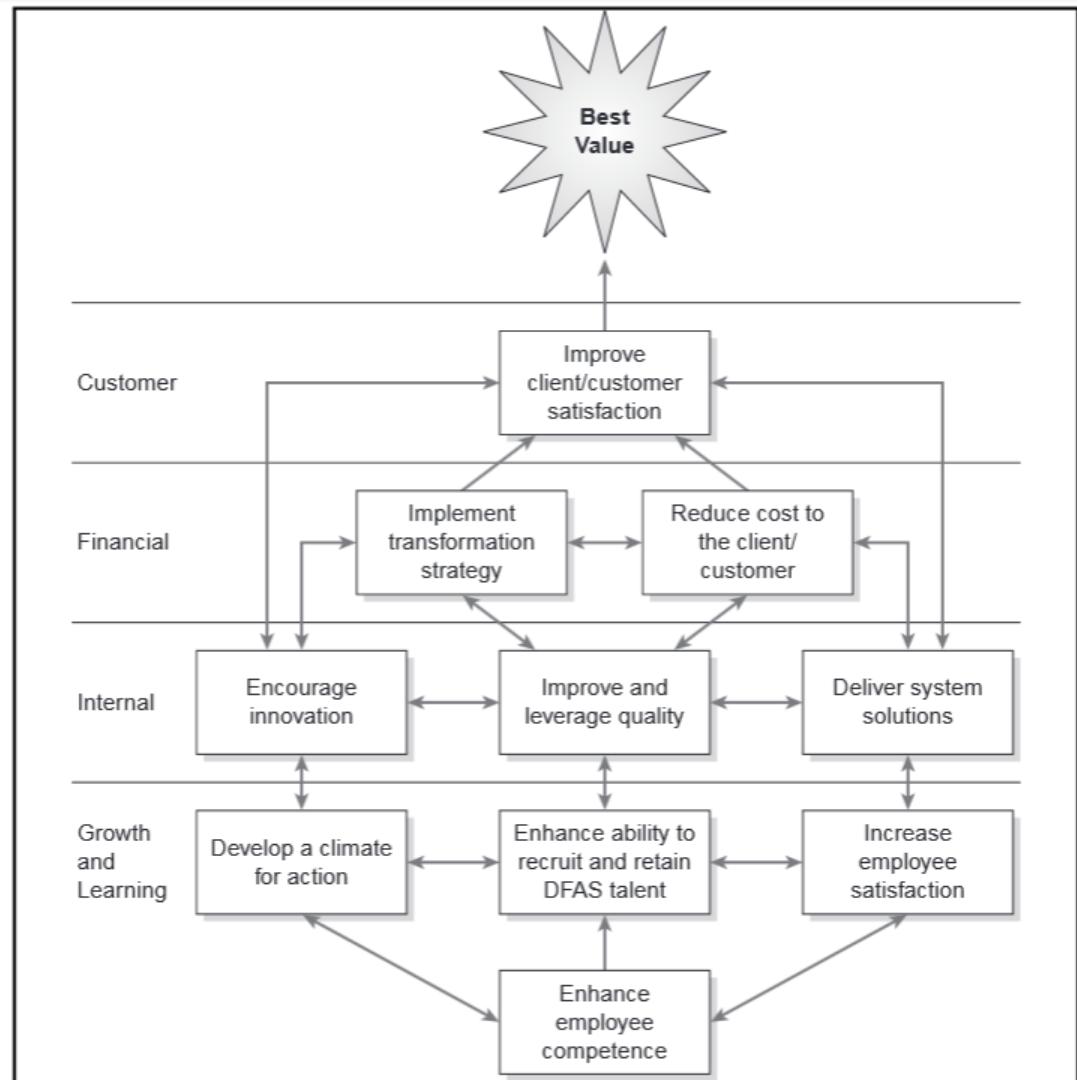
Steps in a strategic management system:

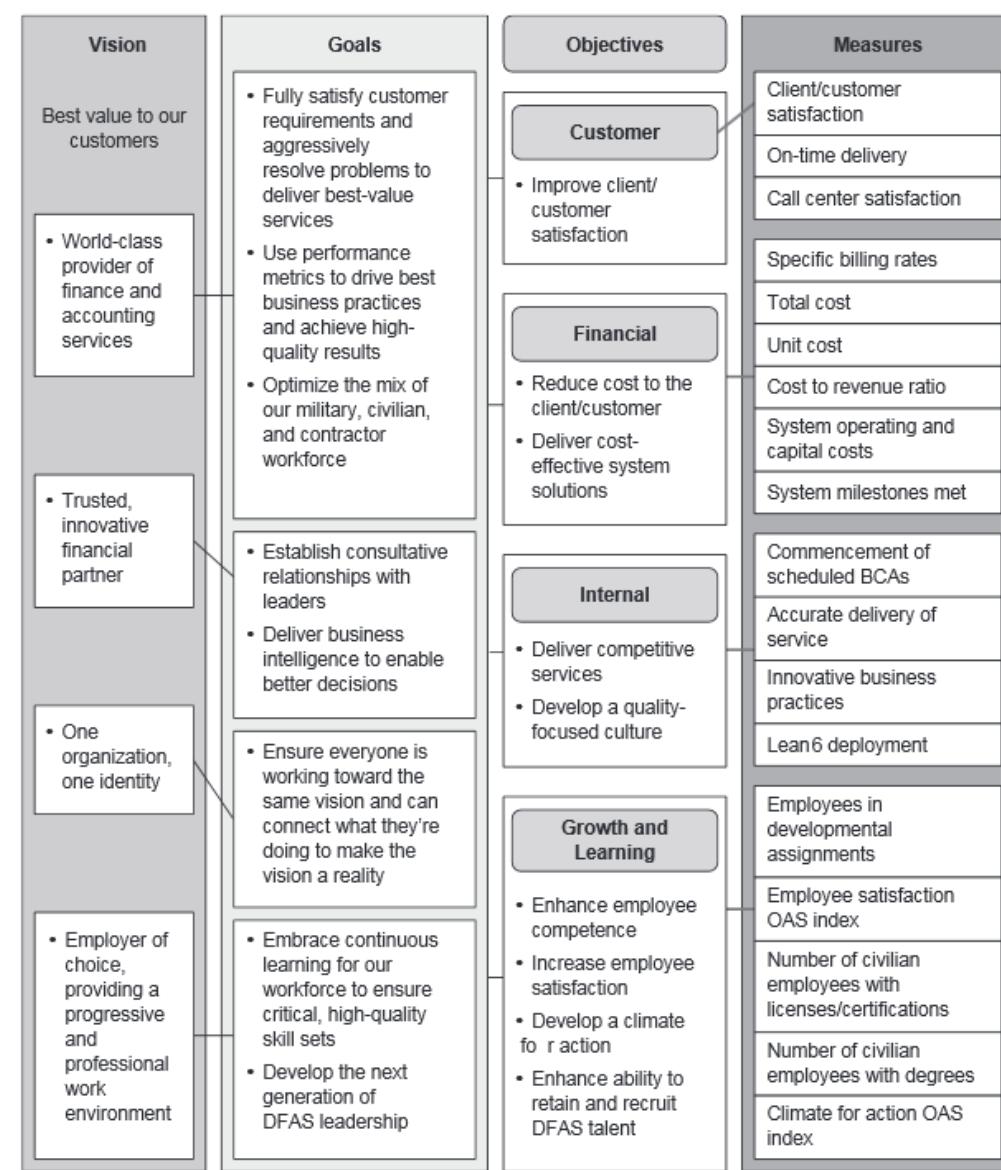
1. Clarify and translate **vision and strategy**
2. Communicate and link strategic objectives and measures
3. Plan, set targets, and align strategic initiatives
4. Enhance strategic feedback and learning

Corporate BSC

Cascading down to units

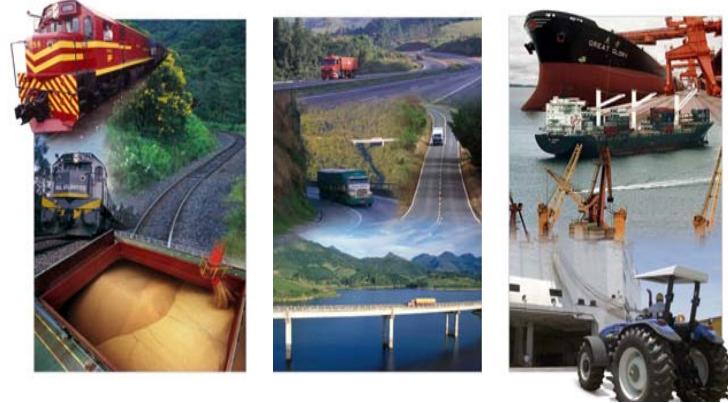
Don't ignore relationships between units





Exercise

Consider a Logistics Service provider, specialized in multimodal transportation.



Suggest some measures which could be used in each of the BSC quadrants.

Financial Issues	Customer Focus
Internal Perspective	Organizational Learning



Benchmarking



Definition

"... a structured process for learning from the practice of others, internally and externally, who are leaders in a field or with whom legitimate comparison can be made"

clean sheet of paper approach, without preconceived ideas, with third-party assistance

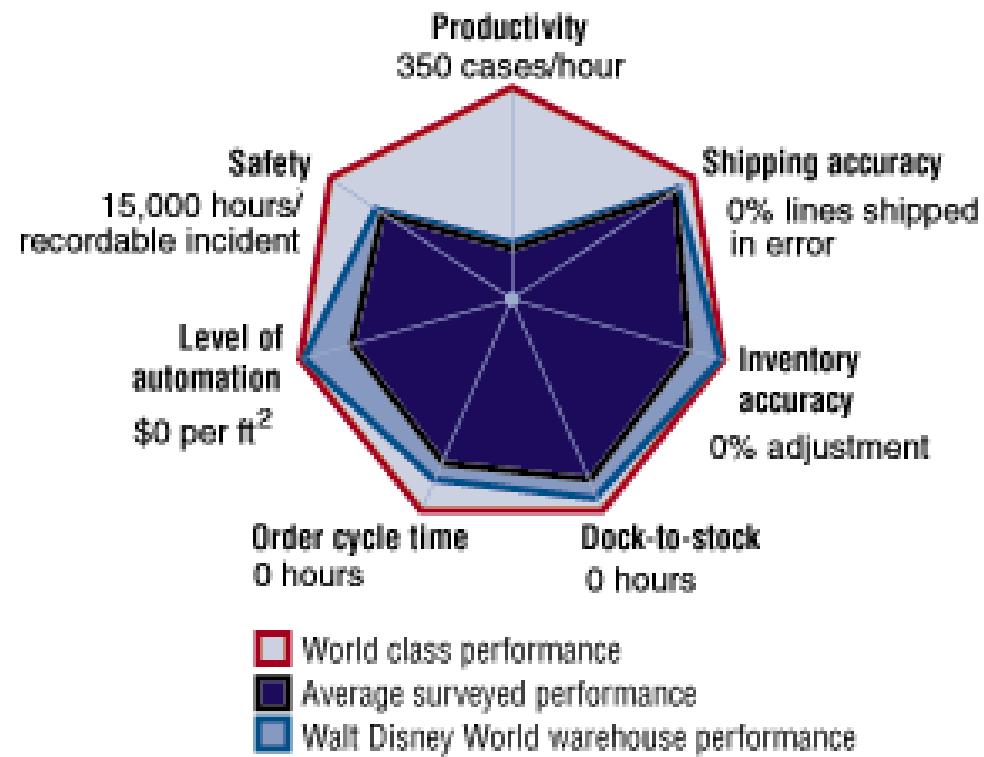
Objective

"... to make changes that lead to continuous and to quantum-leap improvements in products, processes and services that result in total customer satisfaction and competitive advantage."

Types

Internal - external or competitive - functional or "out-of-the-box" - generic

Example 1



Example 2



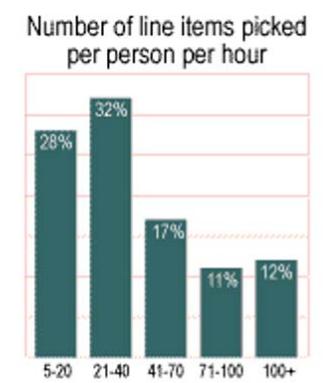
MMH benchmarking study

warehouses handling different products: industrial products, electronics, medical, automotive, paper and many others

on average, each facility requires a total of 57 warehouse workers to support a two shift operation. While a few warehouses run extended shifts, the average worker is on the job 8 hours a day.

annual inventory turns for each warehouse vary widely. About 40% of respondents say they have four or fewer turns a year. Another 28% say five to eight turns. The remaining one-third of respondents report nine or more inventory turns annually

speed of handling inventory and filling orders is a top priority these days. The average dock-to-stock time for receipts is just 5 hours. Meanwhile, the typical order is picked and shipped either the same day as received or the next day.



Example 3



The top 10 metrics keeping warehouse managers up at night

Unsurprisingly, different warehouses and distribution centres each employ a different set of metrics to monitor their performance. The respondents in the WERC report listed a total of 34 metrics used to measure their performance levels.

Table 1 displays the top 10 metrics being managed in warehouses and distribution centres and how these have changed since the 2016 study. The top three metrics - *average warehouse capacity used*, *order picking accuracy* and *peak warehouse capacity* - indicate that capacity and quality are currently taking priority for warehouse managers.

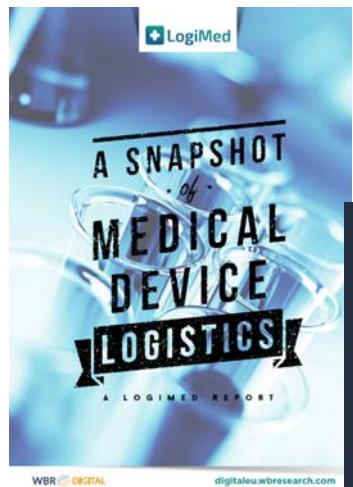
Interestingly, *contract employees to total workforce* jumped from the 48th place in 2016 to the 4th top metric in 2018, perhaps unsurprising given the current shifting demographics within the UK workforce and the effects of Brexit impacting on the availability of labour.

Top 10 metrics	2018	2017	2016
1. Average Warehouse Capacity Used	1	1	2
2. Order Picking Accuracy (percent by order)	2	2	3
3. Peak Warehouse Capacity Used	3	4	7
4. Contract Employees to Total Workforce	4	7	48*
5. On-time Shipments	5	3	1
6. Overtime Hours to Total Hours	6	6	45*
7. Part Time Workforce to Total Workforce	7	5	46*
8. Cross Trained Percentage	8	12	49*
9. Annual Workforce Turnover	9	25	20
10. Inventory Count Accuracy by Location	10	10	19

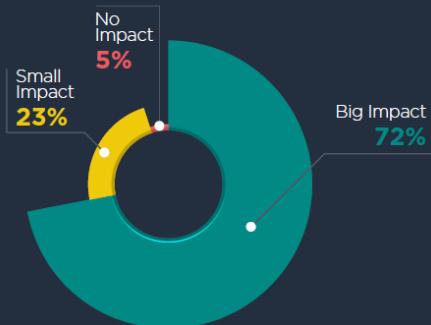
*In 2016, the total number of metrics in the study totalled 55

Table 1

Example 4



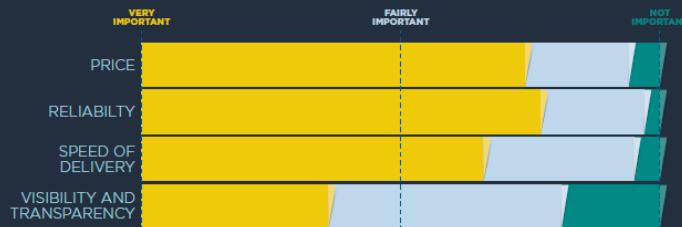
HOW MUCH OF AN IMPACT DOES CONGESTED TRANSPORTATION INFRASTRUCTURE HAVE ON YOUR LOGISTICS OPERATIONS AND YOUR ABILITY TO SERVE CUSTOMERS ON TIME AND ON QUALITY?



72% report that congested transportation infrastructure has a big effect on the ability to deliver on time and on quality.

The supply chain operations of nearly three quarters of our respondents are affected in a big way by congested transportation infrastructure. A further 23% of respondents think that it has a small impact.

HOW IMPORTANT DO YOU THINK THE FOLLOWING FEATURES ARE FOR YOUR CUSTOMERS:



Reliability is considered to be the single most important feature for customers

Maintaining a reliable supply is considered to be the number one priority for customers, with price coming in a close second. Speed of delivery was named as the third biggest customer priority, followed by visibility and transparency.

HOW IMPORTANT IS DIGITALISATION TO THE SUPPLY CHAIN OF MEDICAL DEVICE COMPANIES?

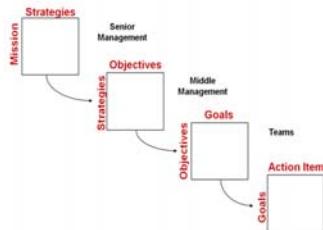
Fairly important	57%
Very important	43%
Not important	0%

100% of respondents think that digitalisation of the supply chain is important

Another important area of modernisation is the digitalisation of supply chain processes, and on this subject the industry is even more united than over the question of big data. 43% of respondents believe that digitalisation will be very important, and a further 57% that it will be fairly important.



“Hoshin kanri”

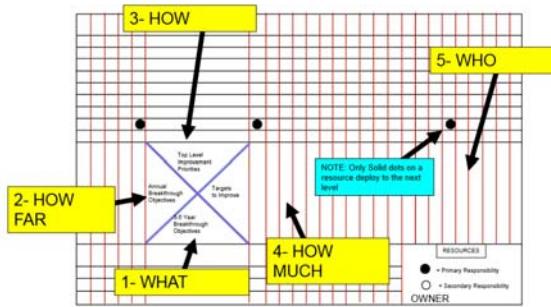


方针 管理

Hoshin = Direction

Kanri = Execution





Top Level Hoshin Planning Matrix

Top Level Improvement Priorities

Annual Policy Breakthrough Objectives

Target to Improve

Breakthrough Objectives

Operating Profit 12% to 15%

Inventory Accuracy to 99%

3.65 Sigma Total PPM

On-time Delivery 14+ Day Quick Fix

WESCO Sales \$1B MM

Uniserv Sales of \$2MM

Achieve Bookings Plan

Complete Kanbans to Plan

Complete Service Improvements to Plan

Complete Cellulization to Plan

Reduce Scrap to \$2.2MM by 12/01

Reduce Voluntary Turnover to 3%

Increase Incremental Average Sales \$1MM by 12/01

Steve Petres

Nancy Buckley

Fred Burleson

Jim Gruber

Dave Niles

John White

Paul Lunderud

Dave DeAngelis

John Seltowski

Resources

● Primary Responsibility
○ Secondary Responsibility

Janice Gomez

Data envelopment analysis (DEA)

Data envelopment analysis (DEA)

Uses mathematical programming to obtain a post facto evaluation of the relative efficiency of management of similar decision making units (DMU)

Origin

Charnes, Cooper and Rhodes - 1978

Academics

Extensive academic research to extend original approach

Practice

Increasing popularity !

Used in practice, i.e service sector, such as hospitals, banks, hotels, governmental services, warehouses, ...



Is productivity measurement in Mfg ≠ Services ?

e.g.



Manufacturing

Services

Output	Tangible	Intangible
Uniformity output	High	Low
Uniformity input	High	Low
Process variability	Low	High
Productivity measurement	Easy	Hard
Quality measurement	Objective	Subjective
Level of automation	Higher	Lower
Contact end user/customer	Low	High

(rather black&white view, many in-between situations exist)

Objective of this exploration

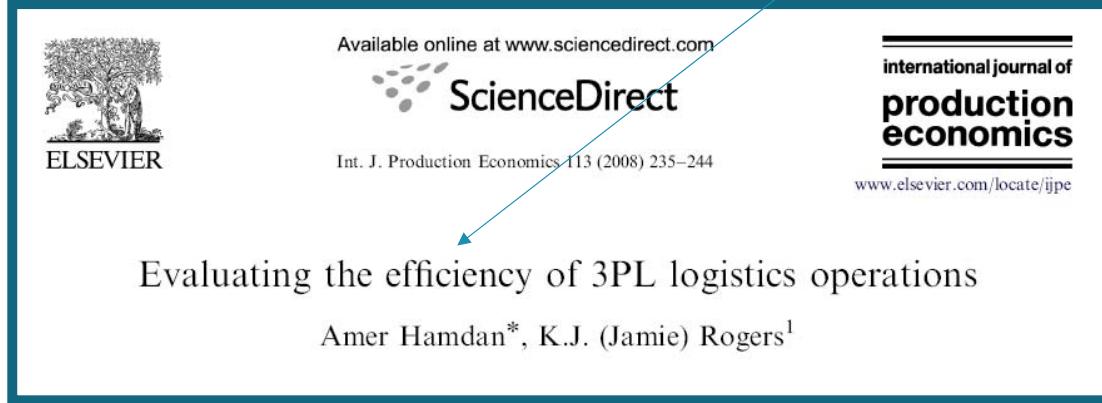
DEA, how does it work ? (math formulation)

Data requirements ?

Output interpretation ?

Strengths – Weaknesses

Based on



Let the DMU_{*j*} to be evaluated on any trial designated as DMU_{*o*} (where *o* = 1, 2...*n*), and then this model is presented as follows:

$$(FP_o) \quad \text{Max } \theta = \frac{u_1 y_{1o} + u_2 y_{2o} + \cdots + u_s y_{so}}{v_1 x_{1o} + v_2 x_{2o} + \cdots + v_m x_{mo}} = \frac{\sum_r u_r y_{ro}}{\sum_i v_i x_{io}}$$

subject to $\frac{u_1 y_{1j} + \cdots + u_s y_{sj}}{v_1 x_{1j} + \cdots + v_m x_{mj}} \leq \frac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij}} \leq 1 \quad \text{for } j = 1 \dots n,$

$$v_1, v_2 \dots v_m \geq 0 \quad \text{for } i = 1 \dots m,$$

$$u_1, u_2 \dots u_s \geq 0 \quad \text{for } r = 1 \dots s,$$

where θ is the objective function value that maximizes the ratio of DMU_{*o*}, which is also called the “relative efficiency score”, v_i the weight for input *I*, u_r the weight for output *r*, x_{io} the value for input *x* of DMU_{*o*} and y_{ro} the value for output *y* of DMU_{*o*}.

outputs

inputs

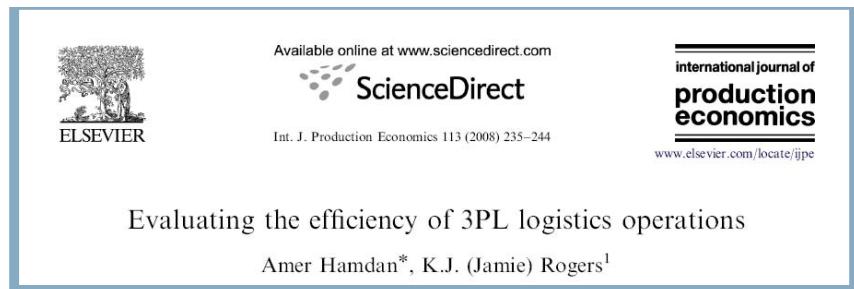
This fractional program (FP_{*o*}) is then replaced by the following linear program (LP_{*o*}):

$$(LP_o) \quad \text{Max } \theta = \sum_r u_r y_{ro}$$

subject to $\sum_i v_i x_{io} = 1.$

$$\sum_r u_r y_{rj} - \sum_i v_i x_{ij} \leq 0 \quad \text{for } j = 1 \dots n,$$

$$v_i \geq 0, u_r \geq 0, \quad \text{for } i = 1 \dots m, \\ \text{for } r = 1 \dots s.$$



Inputs' unit of measure

Input	Unit of measure
Labor	Total annual man-hours
Space	Total warehouse square feet
Technology	Total annual cost of technology
MHE	Total annual cost of MHE

MHE: materials handling equipment.

Table 4
 Outputs unit of measure

Output	Unit of measure
Throughput	Total annual boxes shipped
Order fill	Total annual boxes filled (for complete orders)
Space utilization	Total cubic feet utilized

Discussion exercise

Think back of the MRO order picking case.



Suggest 5 to 10 indicators that management will need to follow up the productivity (performance) of this warehouse.

One of the engineers suggests to automate this warehouse. What is your reaction to this ? What recommendations would you make to management ?



KU LEUVEN

Wrap-up



Important issues

Basics

*What is it about? Management issues for KPI's. What about data and what about reporting?
What are typical good KPI's for ...?*

Special topics

Balanced scorecard (BSC). Benchmarking. Hoshin Kanri. Data envelopment analysis (DEA).

