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WORK DISTRIBUTION IN GLOBAL PRODUCT DEVELOPMENT ORGANIZATIONS

Anshuman Tripathy and Steven D. Eppinger
Massachusetts Institute of Technology – Sloan School of Management

Keywords: Organization Design, Numerical DSM, Distributed Work, Mathematical Programming

Note: The following represents a research project that we are currently involved in with the product development organization of Nokia. Nokia has been gracious is allowing us to share significant data, scaled values of which will be part of this abstract and the accompanying presentation. For confidentiality reasons (strategic and/or sensitive), certain data will not be shared.

1 SUMMARY

Competitive pressures (aggressive cost targets), availability of exceptional and cheaper talent globally, availability of communication media for seamless information flow (aided by advances in collaborative engineering tools and internet technology), advances in IP protection, and several other factors are driving global product development. This has led many firms to replace their traditional, collocated product development processes and organizational structures with new global product development processes and organizations. In an earlier study [1], we identified the role of product architecture, process flow, and PD organization on the same. While literature abounds with prescriptions on modular and integral systems/processes [3, 4, 5], we observed that most components or processes can neither be termed completely modular or integral at the task level. In [1], we also identified the trade-off between lower cost rates and increased work and co-ordination time for globally distributed engineering activities. Here we describe an approach towards structuring work distribution for product development organizations that are distributed globally and are neither modular nor integral, but in-between or complex. We use DSM models to capture both the product development process and the organizational structure. We formulate an optimization model to determine the most effective way to assign the process activities to the distributed work locations.

2 DESIGNING A GLOBAL PRODUCT DEVELOPMENT ORGANIZATION

2.1 Introduction

Nokia is involved in the design, development, manufacture and sale of mobile phones and related services. Their product has evolved from a device in the 1990s to include significant associated services. Nokia's product design and development (PDD) activities are done by various departments distributed globally. In 2008, Nokia underwent an organizational change, moving from an organization comprising of mobile phones, multimedia, enterprise solutions, and other divisions to one comprising of devices, services and solutions, markets, and other divisions. Nokia was interested in identifying the optimized global distribution of work for each of its departments.

2.2 Problem Definition

Identifying the optimized work distribution for lowering costs is a mathematical programming problem and hence the trade-off needed to be identified. As PDD work is distributed globally there are manpower rate differences and work time differences (output from every unit of work time differs globally (different efficiencies)). Thus the trade-off is between lower manpower rates and higher work time. This is moderated by constraints, e.g. those involving capacity, work balance, etc.
Modelling and solving the above trade-off would require identification of both data requirements for the objective function and the constraints. PDD work comprises individual work and work done in collaboration. Each of these could have different efficiencies as work is re-distributed and hence it is important to differentiate and measure each of them [8].

2.3 Data Collection

Having identified the trade-off, we proceeded to develop the model and identify each of the data requirements.

2.3.1 Organization

Since the new Nokia organization would start to crystallize from 2008, we need to initiate work with an existing business group where data could be made available. Such a business group was identified by Nokia. This business group comprised of two main business units A and B. Each business unit comprised of multiple departments which we differentiated between those that were open to re-organization (j) and those that were not (d). It is important to note that departments d and many of departments j do need to collaborate extensively for successful PDD. We identified the various PDD locations and grouped them geographically by regions (k). Increasing or decreasing the total work content at any location would involve costs (similar to setup and setdown costs: SU and SD) and a similar cost would be incurred for increasing the work content for any department SUD (this can be also be viewed as a temporary loss of efficiency due to new employees in the department). We were able to obtain data corresponding to SU_k, SD_k, SUD_k, and ℓ_k (manpower cost rate per man-month), though ideally we may have liked to have SU_{jk}, SD_{jk}, and SUD_{jk}.

Further, while Nokia had been present in most of the locations for many years, there was one location, the GPD location (k=6), where the organization had been established recently, and where learning effects r_k were being observed in both, work and co-ordination, time [2].

Finally the work distribution of each department by region m_{jk} was identified.

2.3.2 Work Content

Nokia's PDD activities occur over 3 phases (planning, definition and development). Planning is common across products and is a calendarized event. Each product goes through the definition and development phases. We developed a DSM (D1) comprising of approximately 200 activities representing the PDD process over the 3 phases. D1 identified the process flow through the activities. It was developed through a series of interviews (approx 30) over two weeks with personnel from different departments and locations. While the interviews during the first week were semi-structured, the second week interviews, held a month later, comprised of debates over a draft D1 DSM.

D1 was enhanced to a numerical DSM (D2) by identifying the departments responsible for each activity. Each activity was done by one or two departments. For each activity, the `individual' work by each department (unit used was man-month) involved was identified. This data (and subsequent ones) assumed that all work is done at the base location (k=1). If an activity involved two departments, we identified the individual work content of each department and the time spent in co-ordination or collaboration. Given the effort used in developing D1, D2 was developed with the help of a core group with experience and visibility of the complete PDD process. This was a multi-day workshop event and was cross-verified with personnel from the planning department. D2 was developed for two different complexities of PDD that the Nokia follows.

D2 was then transformed to an organization DSM (D3) (using weighted average of the complexities) [6, 7] which showed the coordination time between any two departments $c_{j(k=1)j'(k=1)}$. It also calculated, for each department, the individual work time $w_{j(k=1)}$. Similarly we identified $c_{j(k=1)d(k=1)}$.

2.3.3 Efficiencies

A key feature of distributing work globally is that there are differences in work efficiencies. These efficiencies were observed for both work and co-ordination. For work time, through discussions, we were able to establish the relative efficiencies between locations, φ_{jk}. Similarly it was established that there are differences in efficiencies as work is distributed, despite the availability of identical collaborative tools globally. Through successive interviews and discussions we were able to establish the relative co-ordination efficiencies as $\theta_{kk'}$. Ideally we may have wanted to identify $\theta_{jkj'k'}$ ($j \neq j'$). However, it was agreed that the work efficiencies covered the cross-location efficiencies within a department and that there was no significant change between $\theta_{jkj'k'}$ and $\theta_{kk'}$.

2.3.4 Constraint Development

The key constraint identified was that the total work content at any location could not be changed beyond certain limits over the time periods. The organization did not feel that they could either increase/decrease manpower at any location beyond a certain level with respect to the earlier time period.

2.4 Model Development

The key objective of the model here is to reduce cost over a given time period. Thus, the objective function was defined to reduce the sum of work and co-ordination time for departments j and co-ordination time for departments d over all locations k and corresponding setup and set down costs. Taking the available data as belonging to time period t=0, we needed to initialize the work and co-ordination content at each location. Thus, w_{jk} for t=0 was developed using the data $w_{j(k=1)}$, m_{jk}, and φ_{jk}. Similarly the co-ordination time between the departments and between locations (for t=0) $c_{jkj'k'}$ and $c_{jkdk'}$ ($j \neq j'$, $k=/\neq k'$) were developed using $c_{j(k=1)j'(k=1)}$, $c_{j(k=1)d(k=1)}$, $\theta_{kk'}$, and m_{jk}.

For subsequent periods, it was necessary to capture the learning effects of the GPD location. We captured this in the efficiency factors. Thus we were able to develop φ_{jkt} and $\theta_{kk't}$ for t=1,2,..., which is an input to the model.

While one set of constraints was provided as input by Nokia, the optimization model required further constraints. These were defined as:

a) Meet total work and co-ordination time requirements
b) Ensure work balance between work and co-ordination time

The setup/setdown costs in the objective function make the above optimization problem non-linear. Using a small modification we could transform the problem to a LP, thus ensuring convexity and existence of a solution. The final program code (for 3 time-periods) comprises of approximately 14,000 decision variables and more than 8,000 constraints (excluding non-negativity constraints).

(the model is part of the slides)

2.5 Results

We ran the model using various setups and assumptions. We observed potential cost reductions ranging upto 8% for various scenarios. Two interesting insights were that work transfer to the GPD region did not behave monotonically with respect to modularity and that there was significant work re-distribution amongst departments within a region.

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Contact: A.Tripathy
Massachusetts Institute of Technology- A.P.Sloan School of Management,
Operations Management Group
60 Wadsworth Street, E53-388
Cambridge, MA 02142, USA
Phone: 1-617-258-5586
Fax: 1-617-258-7579
atripathy@sloan.mit.edu

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Anshuman Tripathy
Steven D. Eppinger

Massachusetts Institute of Technology
Sloan School of Management

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Motivation: Why GPD?

Ghemawat (2007): firms' globalization is a mix of
- *adaptation* (to market needs)
- *aggregation* (of regional requirements)
- *arbitrage* (to attain efficiencies)

GPD can also be thought of along the above for PD activities
- need to meet market specific requirements
- aggregate regional PD requirements
- arbitrage

Arbitrage:

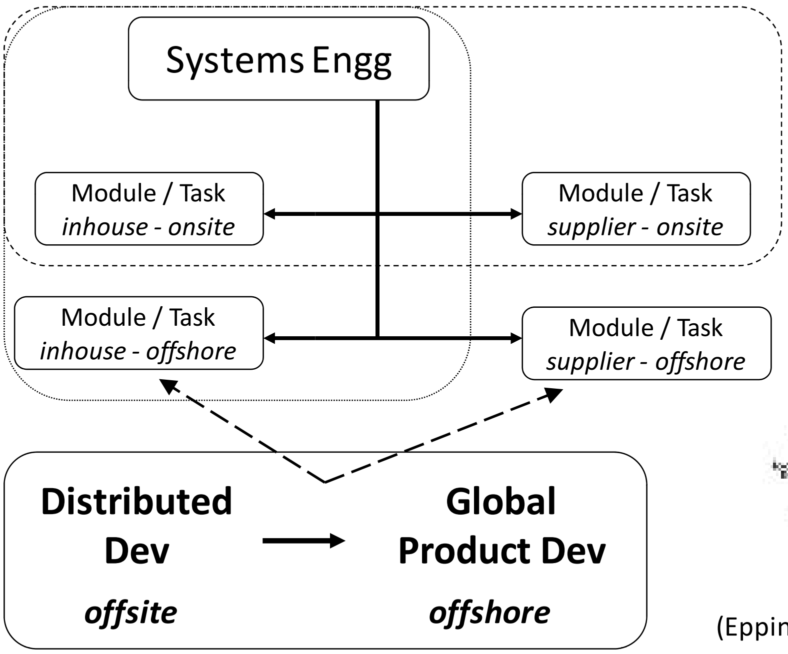
Competence Seeking
- *PB* sources printer from Canon
- *Intel* sets up development centers in Israel, India

Cost Savings
- *Danaher, Textron* setup engg centers in India
- *Honeywell* contemplates low/medium cost region for new dept

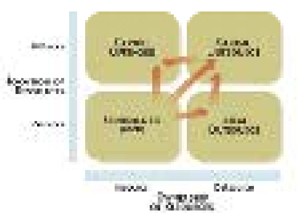
Hedging
- *Danaher* uses flexible workforce
- *Textron* uses mix of own/ out-source workforce

(Tripathy & Eppinger, 2007)

Ownership & Location are different

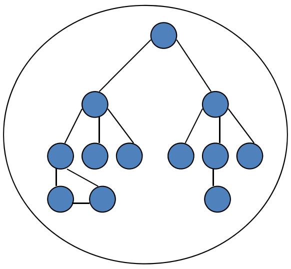


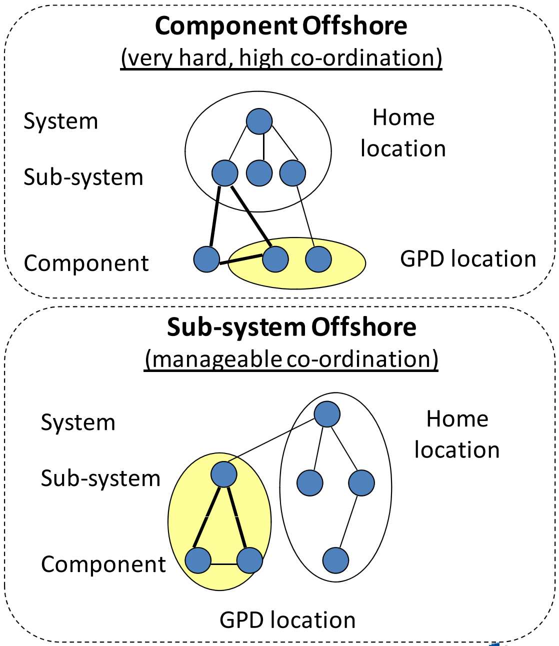
(Ulrich & Ellison (2005))



(Eppinger & Chitkara (2006))

GPD – System Architecture Approach





Strength of Interactions Determines GPD Success

FOLLOW THE FLOW OF INFORMATION!
MANAGE COMPLEX SYSTEMS

Offshoring Decision

$$\sum_i \sum_j \sum_k V(A_{ijkt}) = \min_{x,a}[s_{ijk,k't} + \sum_k \sum_i \sum_j t_{kt}(m_{ijkt} + c_{ijkt})] A_{ijkt} + [illegible] E[V(A_{ijk,t+1})]$$

subject to $\sum_k A_{ijkt} = 1 \quad \forall i, j, t$

$min_{kt} \le \sum_i \sum_j (m_{ijkt} - c_{ijkt}) A_{ijkt} \le max_{kt} \quad \forall k, t$

$\sum_i \sum_j \sum_{k'} s_{ijk,k't} \le B_t \quad \forall t, (k \ne k')$

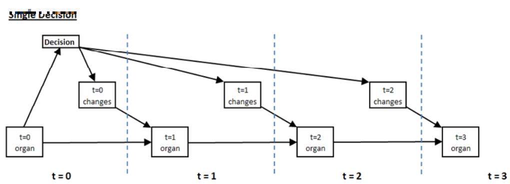
work and co-ordination requirements

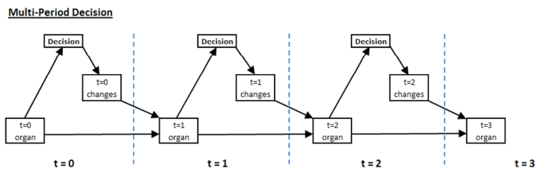
preference and non negativity constraints

$A_{ijkt} \in \{0, 1\}$ work location problem

$A_{ijkt} \in [0, 1]$ work assignment problem

i: component
j: process
k: location
t: time





Single Decision

Nokia Example

Nokia till 2007 mobile phones, multimedia, enterprise solutions, others
from 2008 devices, software and solutions, markets, others

Study One of the business groups in earlier structure, comprising of business units A & B

A: 11 departments (portfolio, architecture, mechanics, etc.)
- 1 department has assigned distribution
- other 10 departments can undergo re-distribution

B: departments have assigned distribution
most future expansions through acquisitions/outsourcing

Is the PD work distribution amongst Nokia's various PD sites (located globally) optimal?

Note: scaled data shown in this presentation

Single Decision: *Nokia Example*

Problem Construct:

Value proposition: total cost
Trade-off: lower manpower rates vs. higher task time
Constraints: task requirements, work balance

Data Needs:

Cost factors: manpower rates, employee hire/fire costs, dept training costs
Task time: tasks, time requirements, relative efficiencies

Need to separate task time between *
- work time: time spent in doing work individually
- co-ordination time: time required to be spent in obtaining/giving information related to own work

** Tripathy & Eppinger (2007)*

Single Decision: *Nokia Example*

Identification of tasks & task time:

Nokia PD Process Overview:

Range Plan. Ph — calendar-based (year t for t+2), common across programs
Product Plan. Ph — program specific, culminates in product definition
Product Dev. Ph — stage gate process

- key deliverables for each phase and stage gates within are known and documented
- `good' overview of tasks/processes followed within the phases/between the stage gates
- need to develop detailed list of tasks to differentiate task time to work and co-ordination time

……….*use process-flow DSM*

Single Decision: *Nokia Example*

Data available: manpower months between stage-gates/phases
- by department j
- by different complexities of programs

2 weeks of interviews across all relevant departments to:

- split manpower data for every department by task
- where 2 departments involved, split task time to
  work time: time spent in performing task responsibilities individually
  co-ordination time: time spent in obtaining /giving information
- all the above data is collected at home base (location k = 1) levels
- systems (process and IT) in place to ensure seamless flow of information between preceding and succeeding processes

Single Decision: *Nokia Example*

confidential

- Range plan. phase is common across programs
- Product plan. and product dev. phase task time depends on program complexity

w_{ijk} individual work time for dept j at location k (here =1) for task i

$c_{i(jk)(j'k')}$ co-ordination time between depts. j and j' located at k and k' (here both 1) for task I

$c_{ij(k=1)j'(k=1)} = \max(c_{ij(k=1)}, c_{ij'(k=1)})$

MANAGE COMPLEX SYSTEMS
FOLLOW THE FLOW OF INFORMATION!

Single Decision: *Nokia Example*

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Process DSM

Task Time

confidential

$c_{jj'}$	A-	A-	A-	A-	A-	A-	A-	A-	A-	OI	A-	B	Mod.
A-AM	247.60				82.65	20.00						51.43	0.6164
A-TM		399.50	2.75		62.13						3.75	9.13	0.8371
A-RM		2.75	789.40		105.00				52.10			4.00	0.8281
A-PgM			0.00	436.80	3.75				67.18	48.75		3.00	0.7807
A-R&D	82.65	62.13	105.00	3.75	1672.80	104.00	15.00	148.65	127.55		4.63	141.00	0.6780
A-M	20.00				104.00	569.00	8.00	68.90	0.00		5.75	11.30	0.7231
A-ID					15.00	8.00	432.30		62.95			36.33	0.7795
A-UI					148.65	68.90		824.30	27.00			102.70	0.7036
A-PM			52.10	67.18	127.55	0.00	62.95	27.00	584.70		26.17	3.58	0.6147
OL				48.75						1194.20		37.50	0.9326
A-PfM		3.75			4.63	5.75			26.17			3.50	
B	51.43	9.13	4.00	3.00	141.00	11.30	36.33	102.70	3.58	37.50	3.50		

Org. nDSM

w_j : work time for dept j

$c_{jj'}$: co-ordination time between dept j and j'

Single Decision: *Nokia Example*

Identification of Locations and Cost Data:

base location (home) defined as location k = 1

other locations identified geographically and PD centers combined within location (k = 2,3,4,5,6)

location k=6 is new GPD center with significant lower costs

costs identified for each location k:

- manpower cost rate ℓ_k
- manpower hiring cost SU_k
- manpower let-off cost SD_k
- department training cost SUD_k

distribution of task content over all locations k for each department j, m_{jk}

recognized the following:

- efficiencies for performing tasks are different across locations
- learning effects are present in GPD location k=6, other locations are steady state

Single Decision: *Nokia Example*

Efficiency

task time = work time + co-ordination time

work time efficiency φ_{jk} identified

co-ordination time efficiency $\theta_{kk'}$ identified (ideally $\theta_{jkj'k'}$)

- used subjective (Likert) scale:

excellent, no challenges	4	time taken = 1 hour
good or average coordination challenge	3/2	
poor, lot of coordination challenges 1	time taken = 2 hour	

- curve fitting (convex decreasing)

$\theta_{kk'(t=0)}$	1	2	3	4	5	6
1	1.00	0.87	0.87	0.71	0.71	0.50
2	0.87	1.00	0.87	0.71	0.71	0.50
3	0.87	0.87	1.00	0.71	0.71	0.50
4	0.71	0.71	0.71	1.00	0.71	0.50
5	0.71	0.71	0.71	0.71	1.00	0.50
6	0.50	0.50	0.50	0.50	0.50	0.71

Single Decision: *Nokia Example*

Learning Effect

identified learning effect r_k at loc k=6
incorporate learning effect through efficiency factors φ_{jkt} and $\theta_{kk't}$
learning effect impact on work time

let $\phi_{jk(t=0)} = \phi_{jk}$

then $\phi_{jkt} = \phi_{jk} / \left(\frac{T_k + t}{T_k}\right)^{-r_k}$

since $T_k >> t$ for k=1..5, learning effects not observed

learning effect impact on co-ordination time

initialize $\theta_{kk'(t=0)} = \theta_{kk'}$

then $\theta_{kk't} = \theta_{kk'} / \min\left(\left(\frac{T_k + t}{T_k}\right)^{-r_k}, \left(\frac{T_{k'} + t}{T_{k'}}\right)^{-r_{k'}}\right)$

since $T_k >> t$ for k=1……5, $\theta_{kk't} = \theta_{kk'}$ when k,k' ≠ 6

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Single Decision: *Nokia Example*

Data Development

work time $w_{jk} = \frac{w_j . m_{jk}}{\phi_{jk}}$ co-ordination time $c_{jkj'k'} = \frac{c_{jj'} . m_{jk} . m_{j'k'}}{\theta_{kk'}}$

➔ transformed 12x12 nDSM to 72x72 nDSM
consider a 5-time period model: t = 1,2,3,4,5
thus we get w_{jkt} & $c_{jkj'k't}$ with $w_{jk0} = w_{jk}$ and $c_{jkj'k'0} = c_{jkj'k'}$ (initialization)

Assumptions Used

$e^{-\beta t} = 0.9$
(base model) capacity constraints
home location: capacity can *(max)* reduce 10% yoy and 15% over 3 yrs
locations k=2,3,4,5: capacity can *(max)* reduce 10% yoy
GPD location k=6: capacity can *(max)* increase 15% yoy
no budget constraints considered
competence preserving: no department (at any location) can reduce to less than 50% original strength

Single Decision: *Nokia Example*

$$\text{Min} \quad \sum_{t=1}^{5} e^{-\delta t}\Big(\sum_{j}\sum_{k}[f_k(w_{jkt}+c_{jkt})]\Big)$$

$$-\sum_{t=1}^{5} e^{-\delta(t-1)}\Big(\sum_{k}[SU_k.\max((\sum_{j}(w_{jkt}+c_{jkt}-w_{jk(t-1)}-c_{jk(t-1)})),0)]\Big)$$

$$-\sum_{t=1}^{5} e^{-\delta t}\Big(\sum_{k}[SD_k.\max((\sum_{j}(w_{jk(t-1)}+c_{jk(t-1)}-w_{jkt}-c_{jkt})),0)]\Big)$$

$$\sum_{t=1}^{5} e^{-\delta t}\Big(\sum_{k}\sum_{j} SUD_{jk}.\max(w_{jkt}+c_{jkt}-w_{jk(t-1)}-c_{jk(t-1)},0)\Big)$$

s.t.

$$m_{jt} \le \sum_{k} w_{jkt}\times\phi_{jkt} \quad \forall j,t \qquad (1)$$

$$c_{jkt} = \sum_{j'}\sum_{k'} a_{jkj'k't} \quad \forall j,k,t \qquad (2)$$

$$c_{jj't} \le \sum_{k}\sum_{k'} c_{jkj'k't}\times\theta_{kk'} \quad \forall j,j',t \qquad (3)$$

$$\frac{c_{jj't}}{m_{jt}} \le \frac{\sum_{k'}(c_{jkj'k't}\times\theta_{kk'})}{w_{jkt}\times\phi_{jkt}} \quad \forall (j,j'),k,t \qquad (4)$$

Other constraints like: (5)

$min_{jkt} \le w_{jkt} - c_{jkt} \le max_{jkt}$ $\forall j,k,t$ (capacity constraints)

$w_{jkt} = 0, c_{jkt} = 0$ (when certain dept cannot be located at certain locations)

$w_{jkt}, c_{jkt} \ge 0$ $\forall j,k,t$ (non negativity)

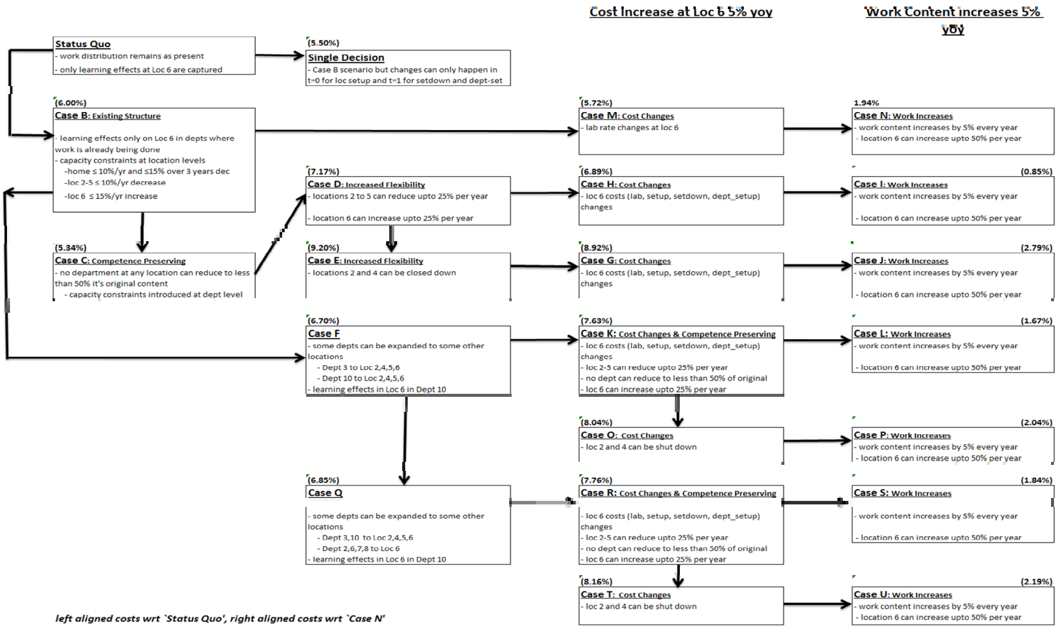
Single Decision: *Nokia Example*

- Non-linear objective function due to location setup/setdown costs, dept setup
- Use transformations to linearize objective function
- Constraint set is linear, and hence convex
- We get LP setup ➔ corner solution exists

We look at alternate scenarios:

- Allow locations k=2,3,4,5 capacity to *(max)* reduce upto 25% yoy and GPD location k=6 capacity to *(max)* increase 25% yoy
- Allow locations k=2,4 to be shut down
- Allow dept 3,10 to be performed at locations k=2,4,5,6
- Allow dept 2,6,7,8 to be performed at GPD location k=6
- Introduce cost increase of 5% yoy at GPD location k=6
- Total work content of business group increases 5% yoy

Single Decision: *Nokia Example*



the above is a reflection of potential results, not actual results

Summary

- The practice of Global Product Development is becoming prevalant: accompanying it is the challenge of organizing it
- System architecture will play a very critical role in determing the organization of GPD
- DSM can help identify and quantify the interactions and interdependencies leading to designing of successful GPD organizations
- Developed an example to show how nDSM can help identify the work distribution in a GPD organization