

Flexibility and Capacity Planning

- **What is flexibility?**
- **GM examples**
- **Lessons from Flex Cap software**
- **Flex Cap model**
- **Flexibility principles**
- **Reference – Jordan, Graves “Principles on the Benefits of Manufacturing Process Flexibility,” Management Science, April 1995**

What is flexibility?

- Ability to respond to change
- What type of changes?
 - Demand volume
 - Demand mix
 - Product features
 - Process or technology changes
 - Job priorities
 - Process yield
- How responsive?

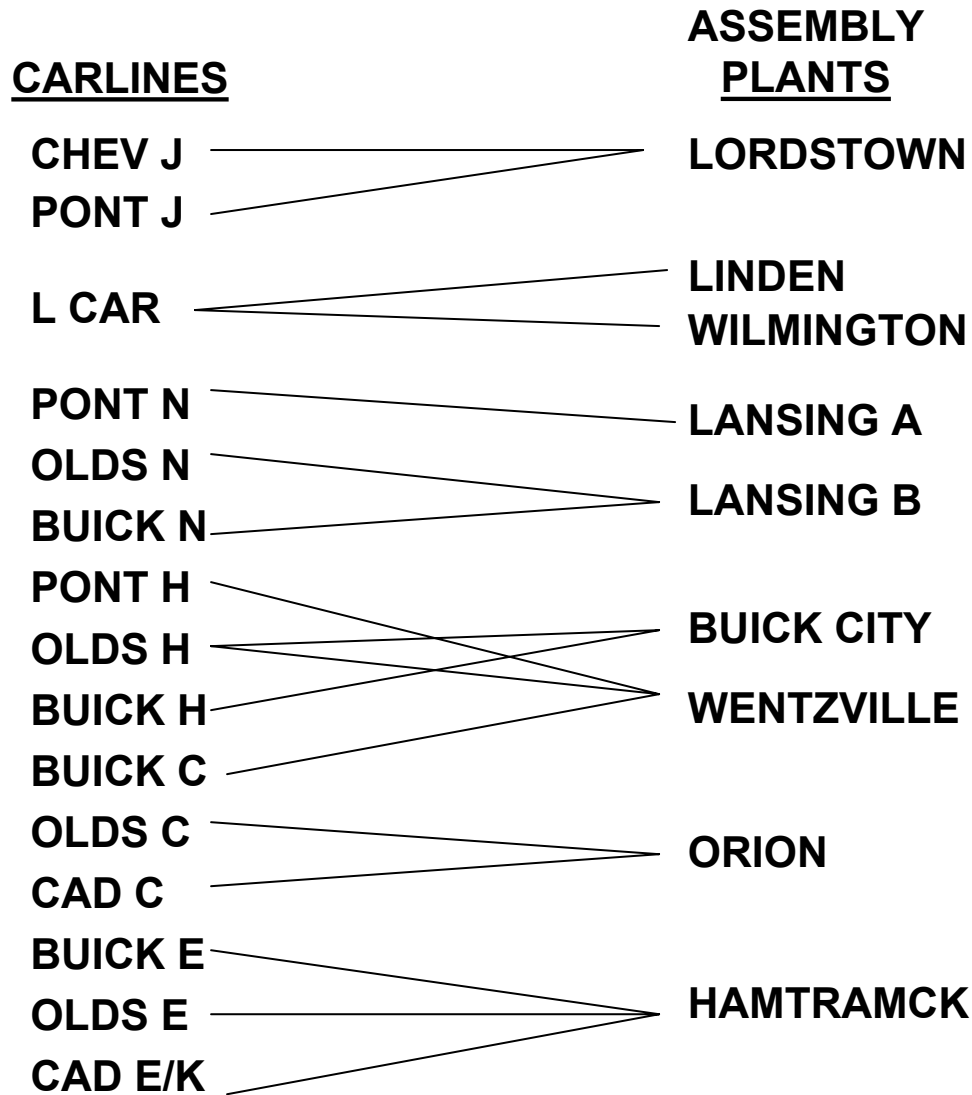
How to achieve flexibility?

- **Flexible processes**
- **Short setups or changeovers**
- **Flexible work force**
- **Excess capacity**
- **Overtime**
- **Out sourcing or subcontracting**
- **Product design, e. g., modularity, common components, postponement**
- **Contracts, e.g., options**

BACKGROUND

- **Forward planning in automotive industry for allocating products to assembly plants**
- **Flexibility:**
 - **Ability to build different product types in the same plant at the same time**
- **Motivation:**
 - **Product demand is VERY uncertain. average forecast error > 50% !**
 - **Cost of unfilled demand or poorly utilized capacity is very high.**
 - **Flexible capacity is very expensive.**

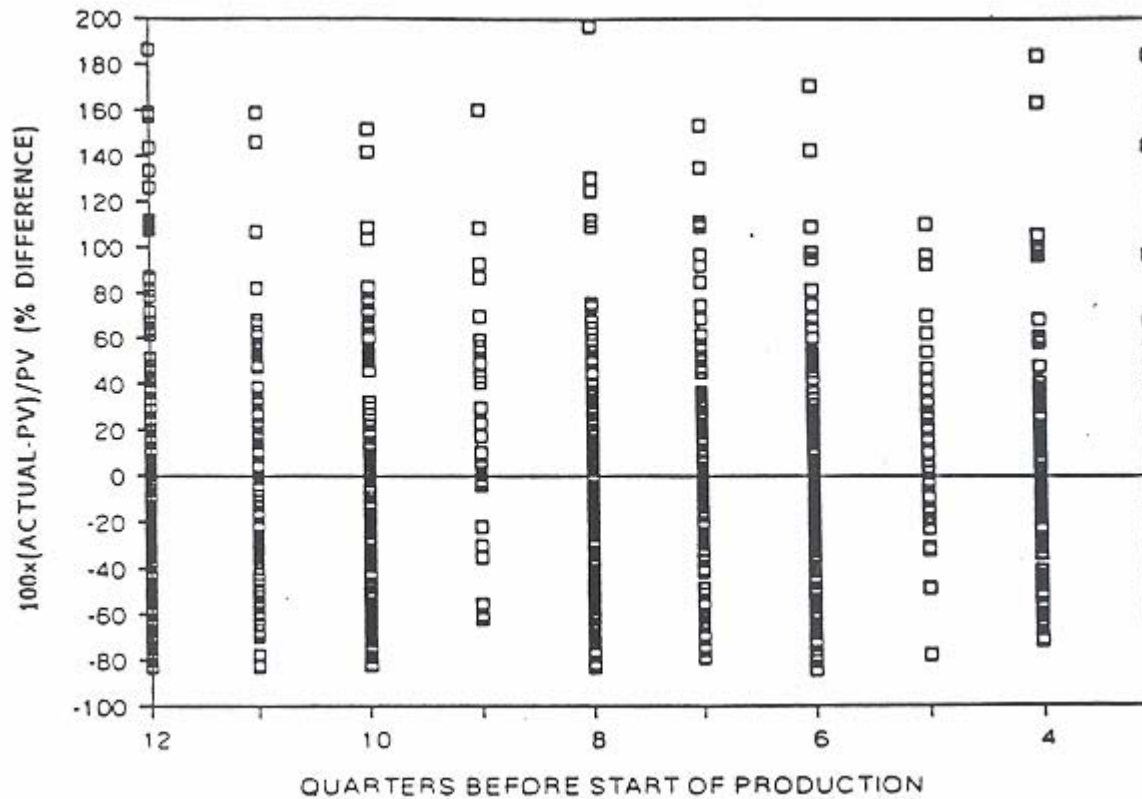
BOC MY PRODUCT ALLOCATIONS



IS THIS ENOUGH FLEXIBILITY?

PLANNING VOLUME UNCERTAINTY

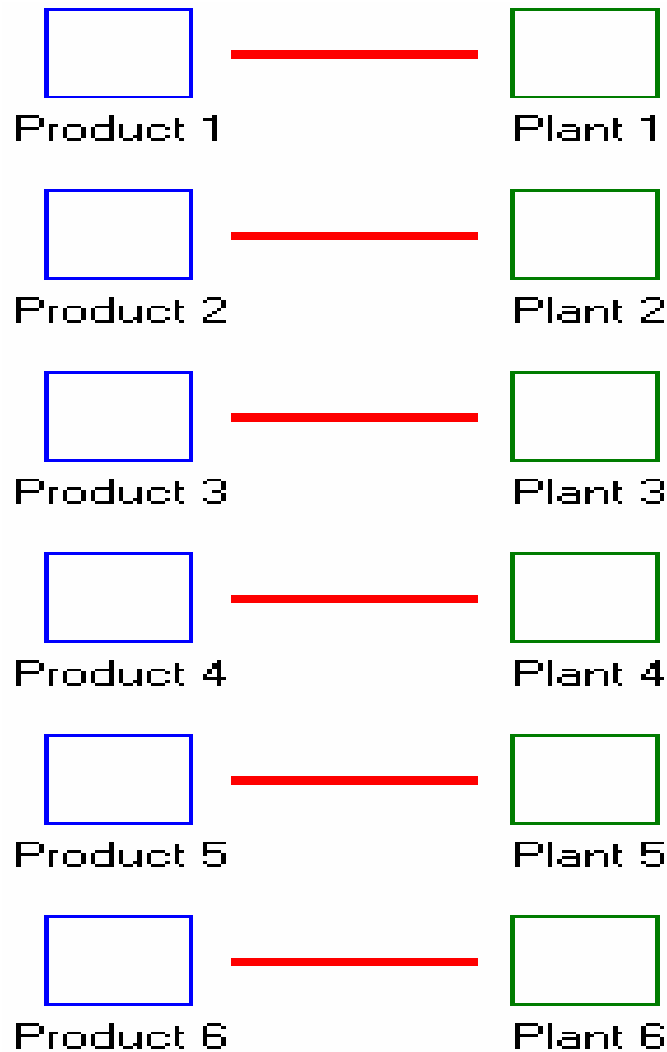
PLANNING VOLUMES FOR MY 85-89 NAMEPLATE-CARLINES COMPARED TO ACTUAL PRODUCTION:



AVERAGE UNCERTAINTY

MY 85-89 NAMEPLATE-CARLINE PLANNING VOLUMES COMPARED TO ACTUAL PRODUCTION

<u>QUARTERS BEFORE SOP</u>	<u>AVERAGE ABSOLUTE DIFFERENCE</u>
12	54%
8	44%
4	37%



Dedicated System

Sales:	528.26
Shortfall:	76.26
Utilization:	88.11%

X_{ij} : amount produced at plant i for product j

S_j : shortfall for product j

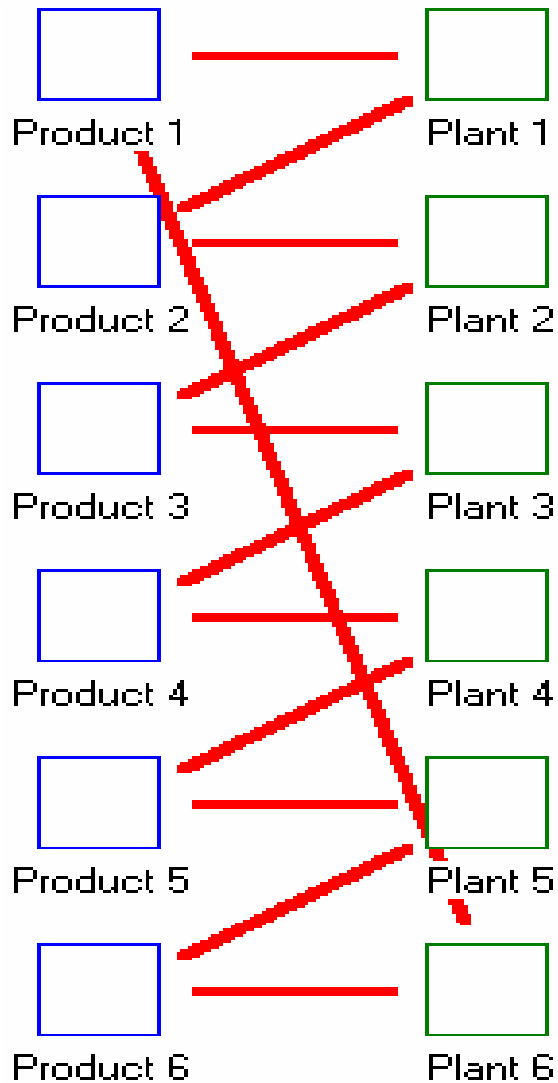
$$\text{Min } \sum_j S_j$$

$$\sum_j X_{ij} \leq C_i \quad \text{for all plants } i$$

$$\sum_i X_{ij} + S_j \geq \tilde{D}_j \quad \text{for all products } j$$

- **What is the best way to add flexibility to the system?**
- **What are the benefits?**
- **How much flexibility do you need to add?**

	sales	shortages	Util.
Dedicated	531	71	88.5 %
1 link	534	68	89.0 %
2 links	540	62.5	90.0 %
3 links	545	57	90.9 %
4 links	552	50.5	91.9 %
5 links	559	43.4	93.1 %
6 links	572	29.7	95.3 %
Total flex	572	29.6	95.4 %



Limited Flexibility

Sales: 569.39
 Shortfall: 35.13
 Utilization: 94.96%

Total Flexibility

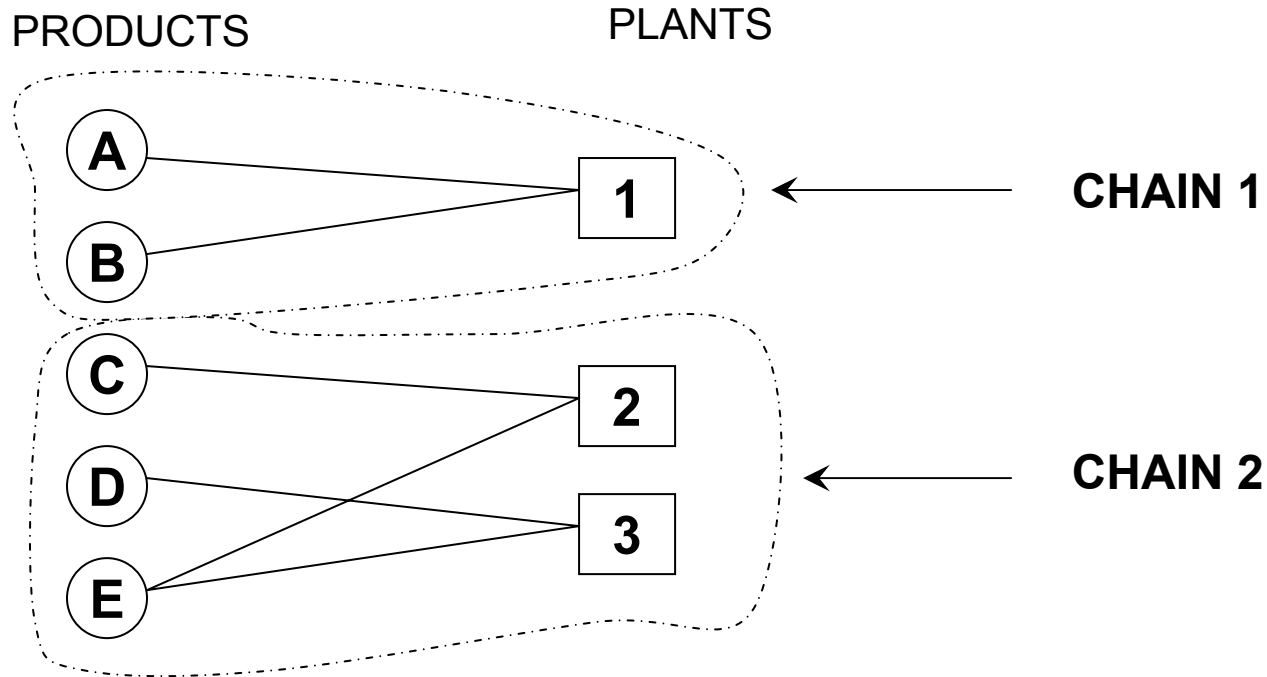
Sales: 569.40
 Shortfall: 35.12
 Utilization: 94.96%

FLEXIBILITY PRINCIPLES

- ***A LITTLE FLEXIBILITY GOES A LONG WAY!:***
 - **SMALL AMOUNT OF FLEXIBILITY APPROPRIATELY USED YIELDS MOST OF THE BENEFITS OF TOTAL FLEXIBILITY**

- ***“CHAINING”:***
 - **ADDING FLEXIBILITY TO “CHAIN” PLANTS AND PRODUCTS TOGETHER IS MOST EFFECTIVE**

CHAINS



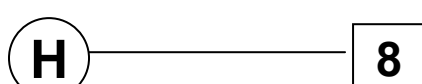
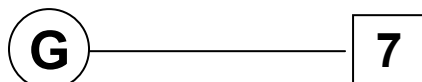
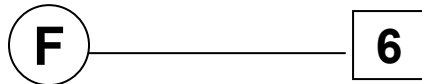
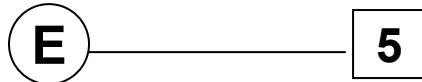
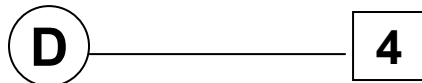
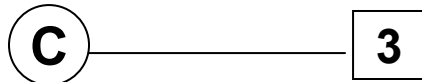
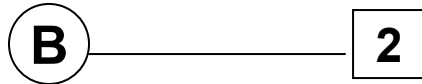
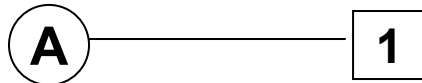
PRODUCTS ASSIGNED TO PLANTS ARE CONNECTED TO LINKS AS SHOWN

A CHAIN IS DEFINED SUCH THAT A PATH CAN BE TRACED VIA LINKS FROM ANY PRODUCT OR PLANT TO ANY OTHER PRODUCT OR PLANT WITHIN THE CHAIN.

- **NO PRODUCT IS BUILT BY A PLANT OUTSIDE THE CHAIN**
- **NO PLANT BUILDS A PRODUCT FROM OUTSIDE THE CHAIN**

MULTI-PLANT EXAMPLE

PRODUCTS **PLANTS**

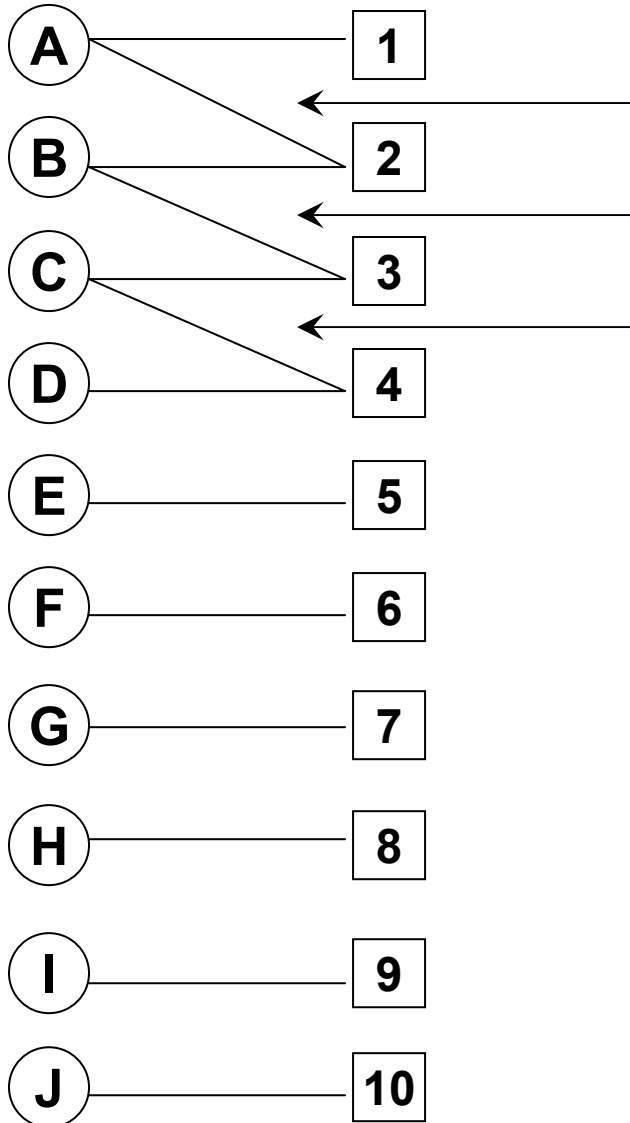


- **DEMAND FOR EACH PRODUCT:**
 - EXPECTED = 100 UNITS
 - STANDARD DEVIATION = 40 UNITS
 - PRODUCT DEMANDS UNCORRELATED
- **CAPACITY OF EACH PLANT = 100 UNITS**

ADD FLEXIBILITY

PRODUCTS

PLANTS



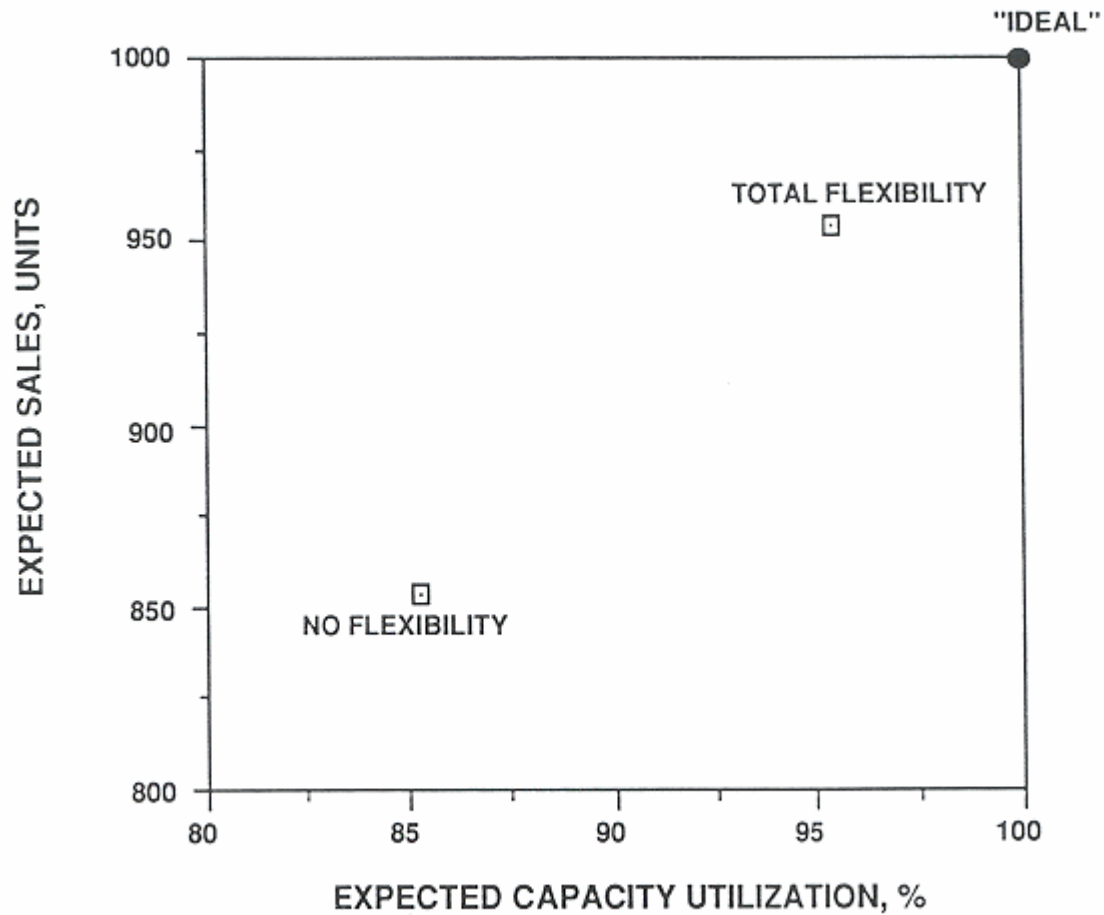
ADD FIRST LINK

ADD SECOND LINK

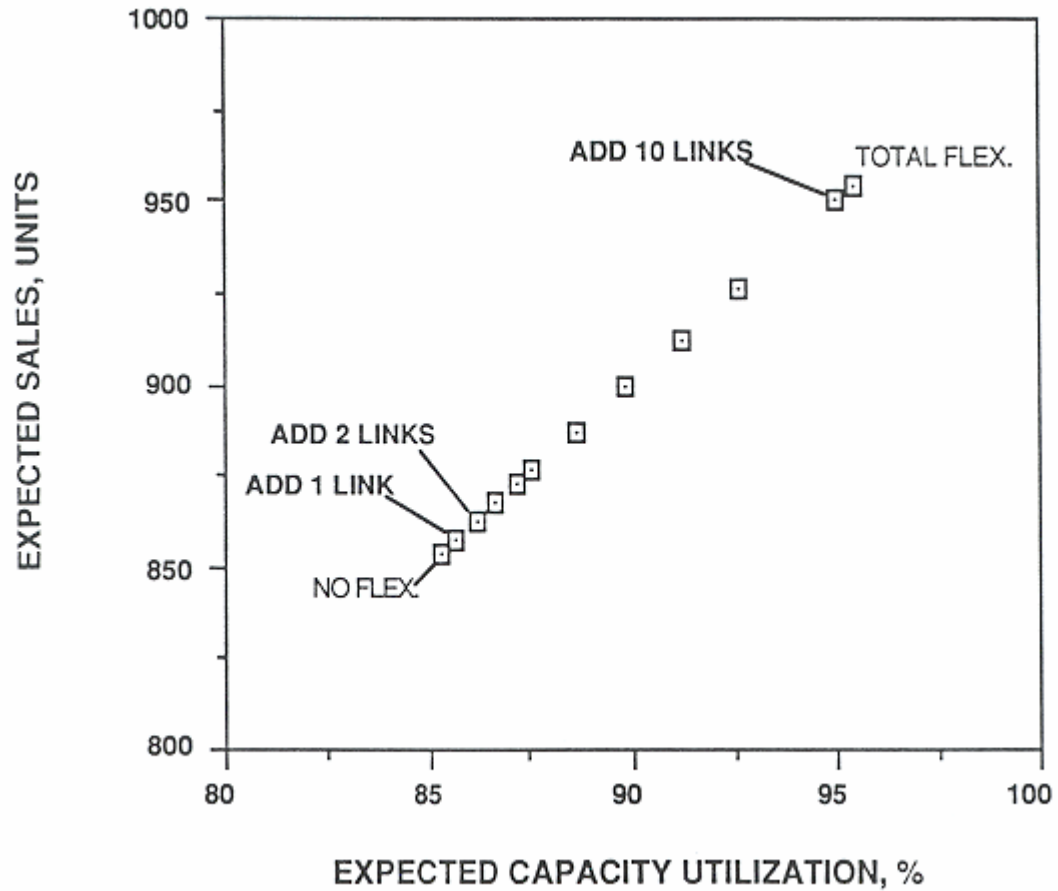
ADD THIRD LINK



NO FLEXIBILITY VS. TOTAL FLEXIBILITY

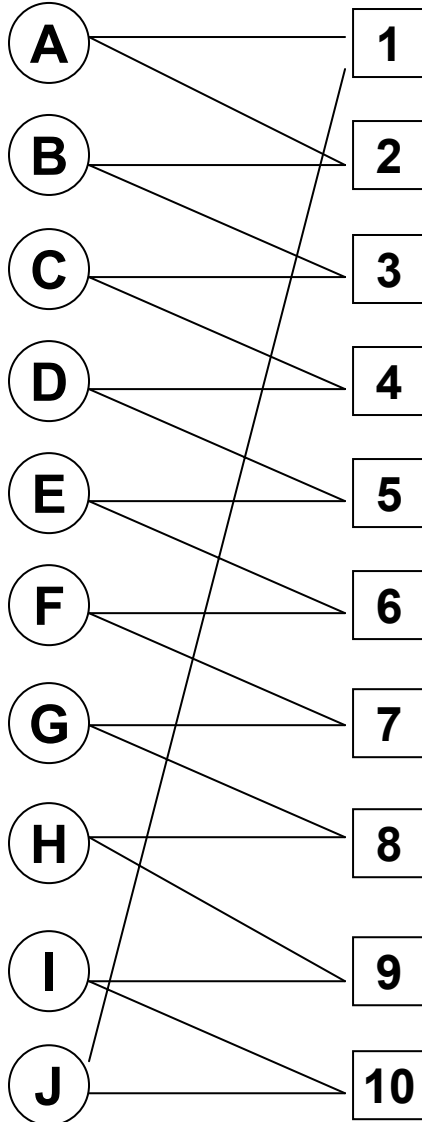


IMPACT OF ADDING FLEXIBILITY



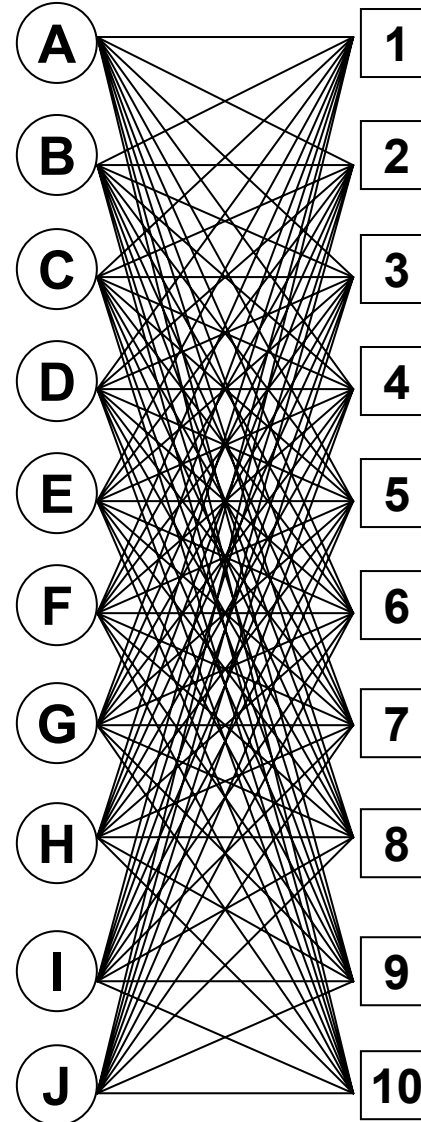
LIMITED FLEX. CAN HAVE THE BENEFITS OF TOTAL FLEX.

PRODUCTS PLANTS



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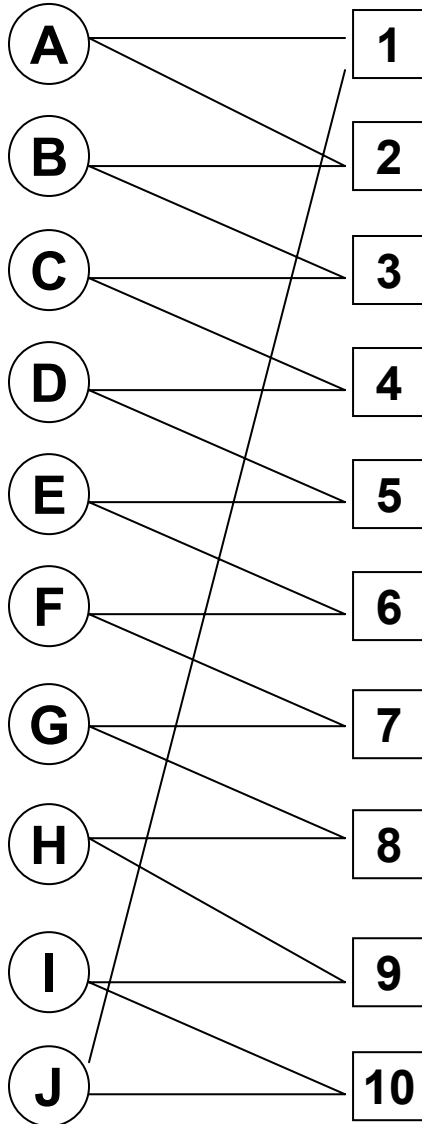
PRODUCTS PLANTS



CHAINING YIELDS THE GREATEST BENEFITS

ONE CHAIN

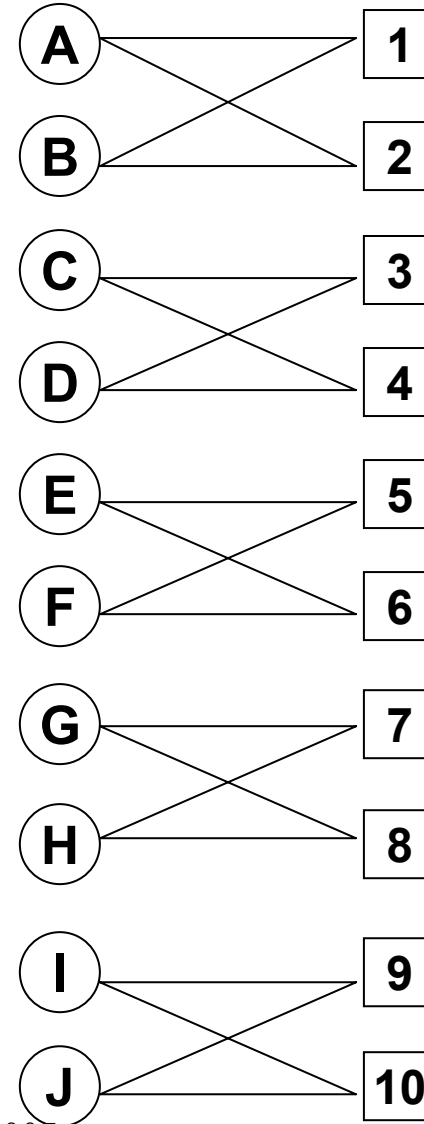
PRODUCTS PLANTS



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FIVE CHAINS

PRODUCTS PLANTS



IMPACT OF CHAINING

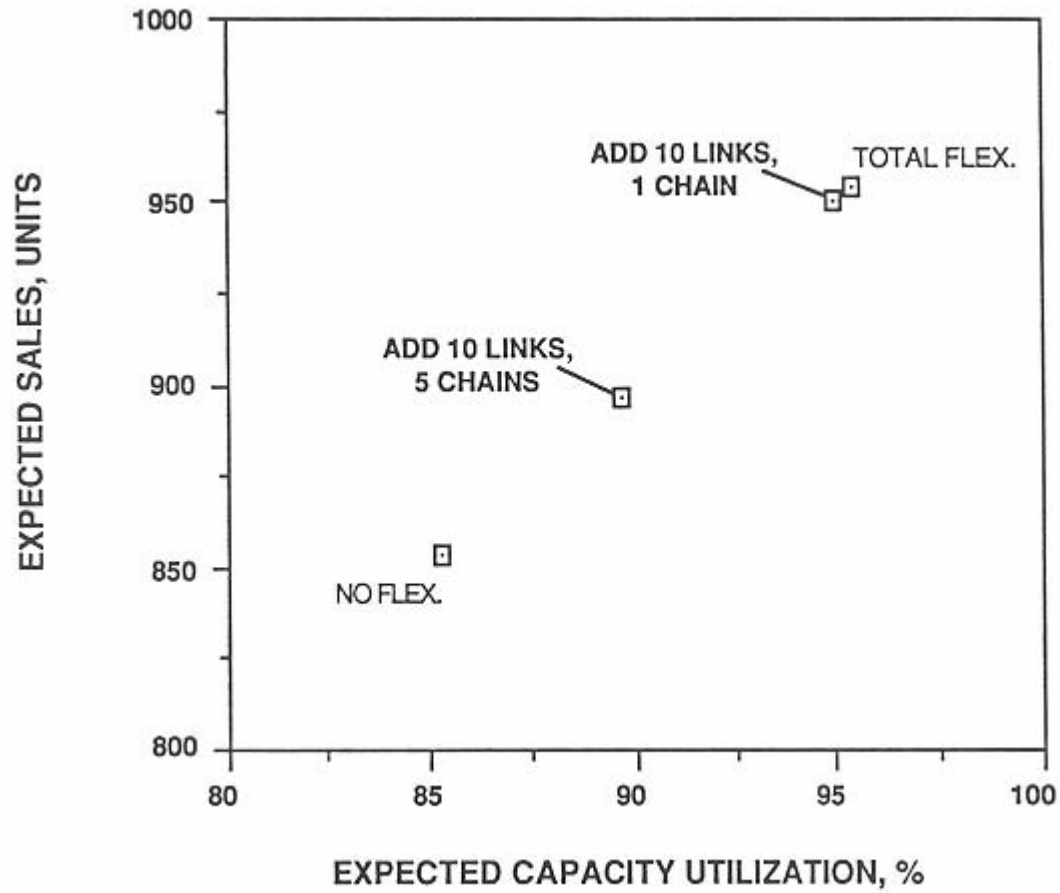
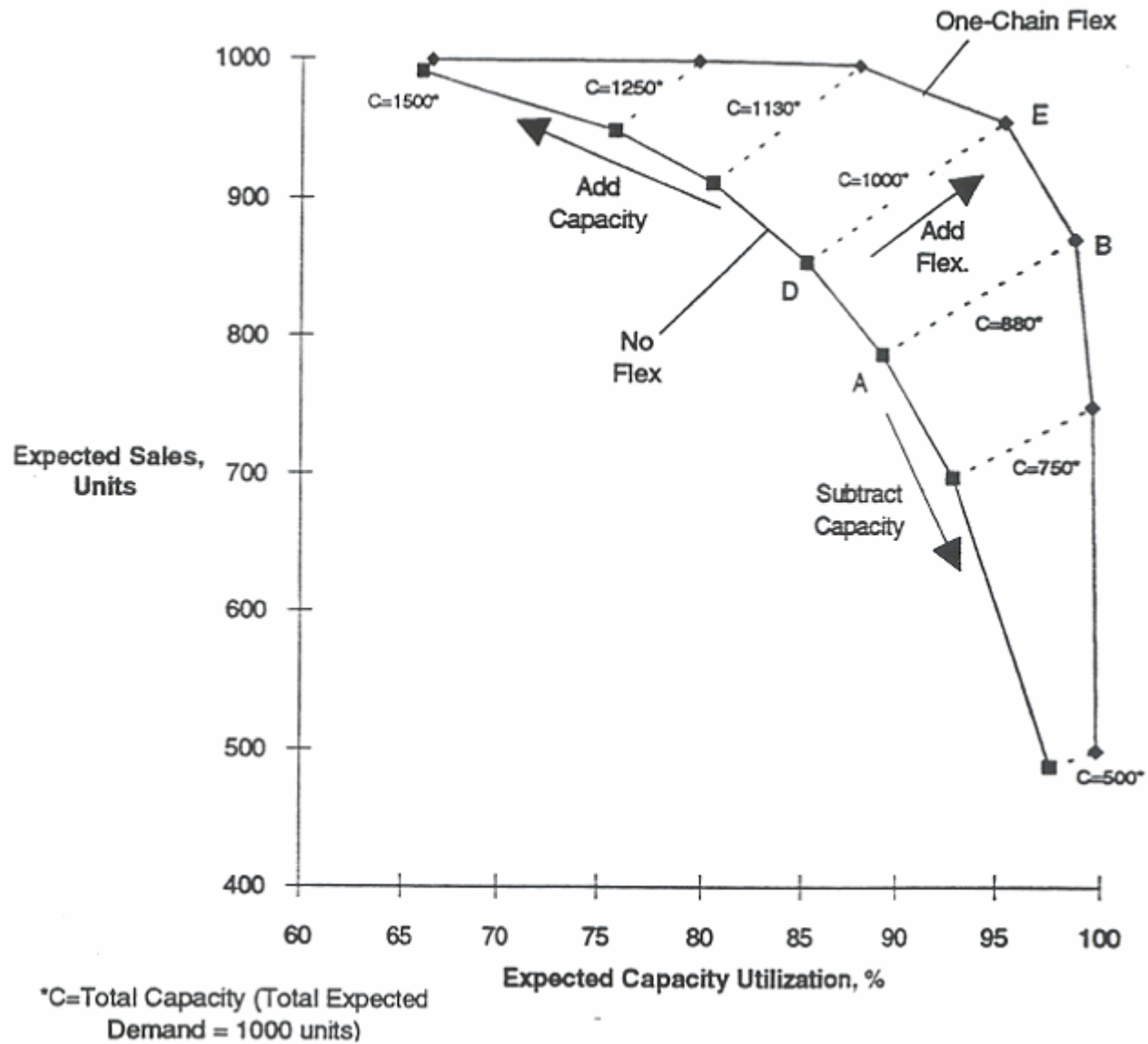
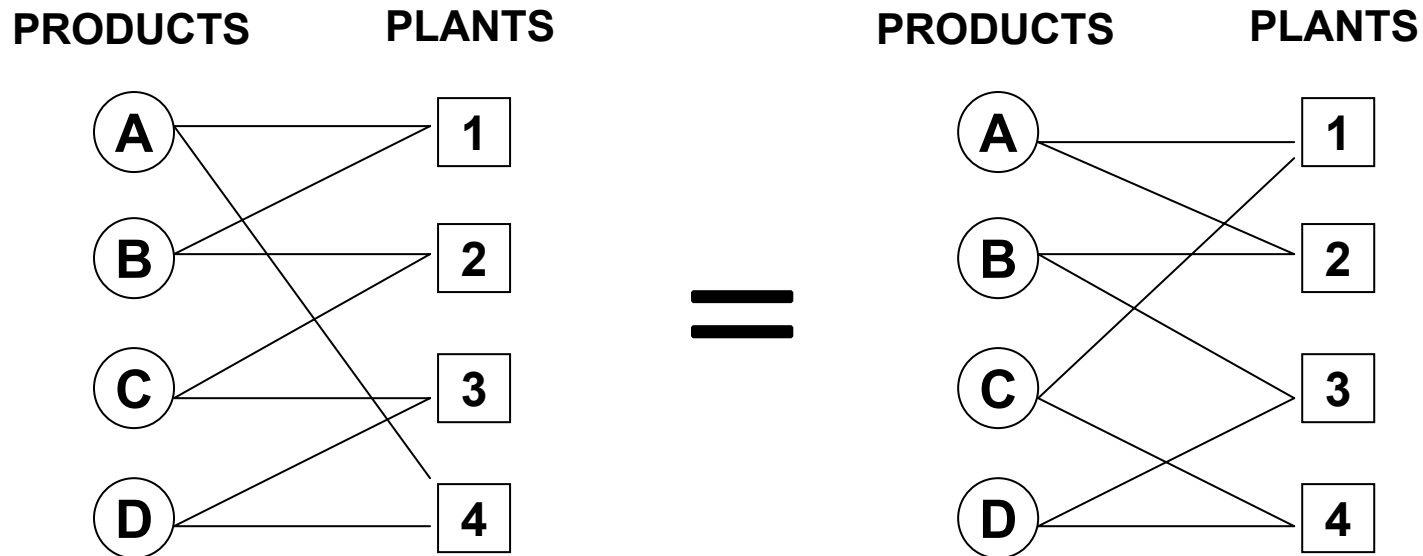


Figure 4 Impact of Capacity Changes on Benefits of Flexibility



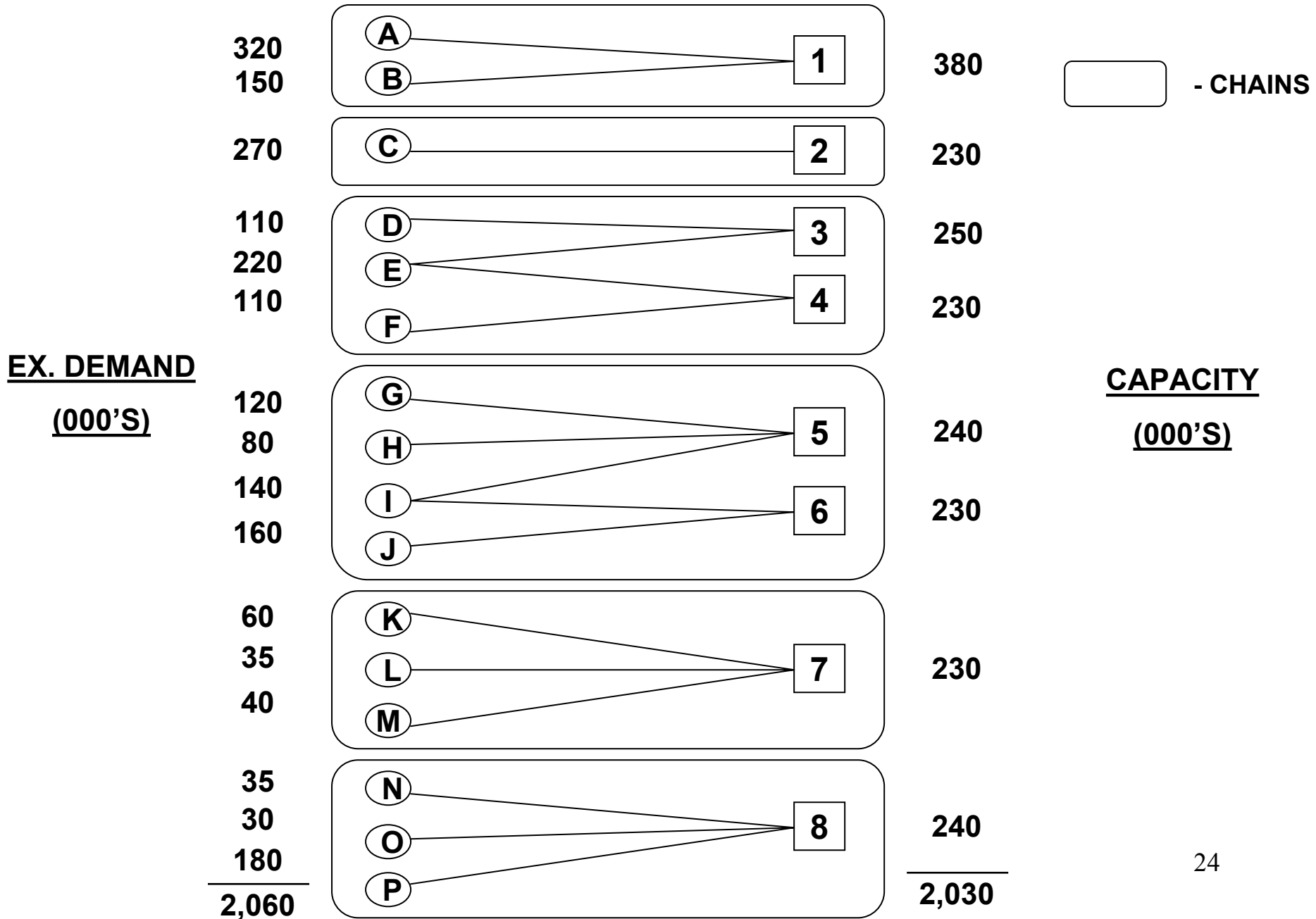
NEGATIVE DEMAND CORRELATION

- **CHAINING MORE IMPORTANT THAN COMBINING NEGATIVELY CORRELATED PRODUCTS**
- **EXAMPLE:**
 - **ASSUME PRODUCTS A AND C NEGATIVELY CORRELATED. THEN THESE CONFIGURATIONS ARE EQUIVALENT IN TERMS OF FLEXIBILITY BENEFITS.**

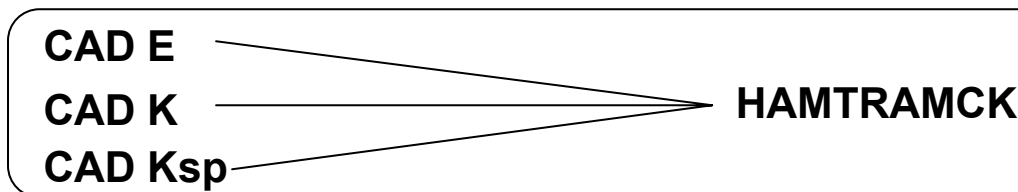
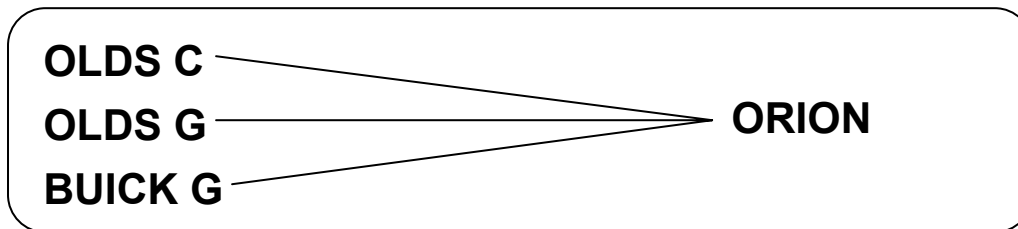
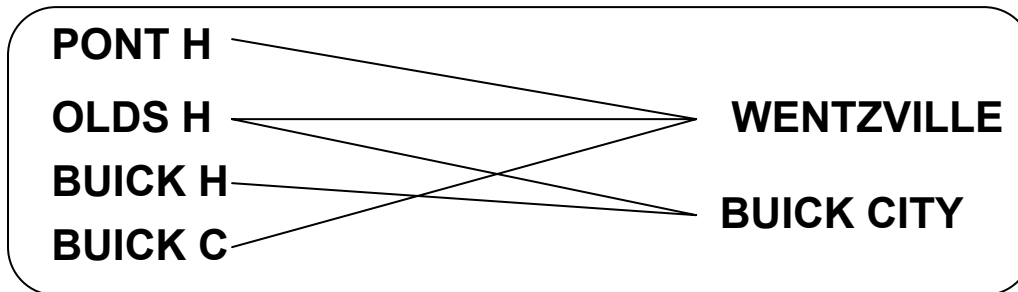
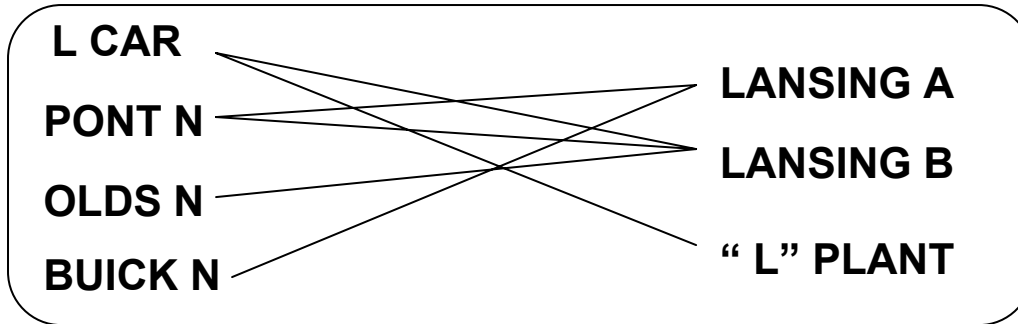
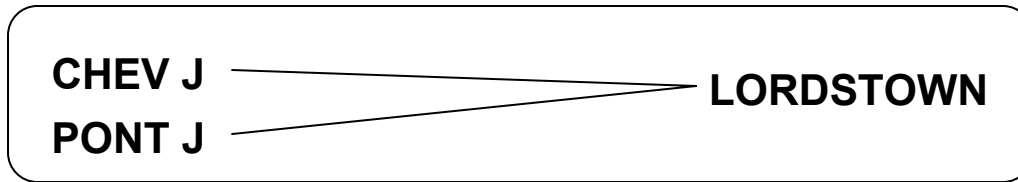


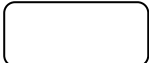
- **PRODUCT CORRELATIONS ARE NOT A KEY FACTOR IN DECIDING WHICH PRODUCTS TO BUILD TOGETHER IN A PLANT, AS LONG AS THE PRODUCTS ARE CHAINED TOGETHER**

"REAL" EXAMPLE

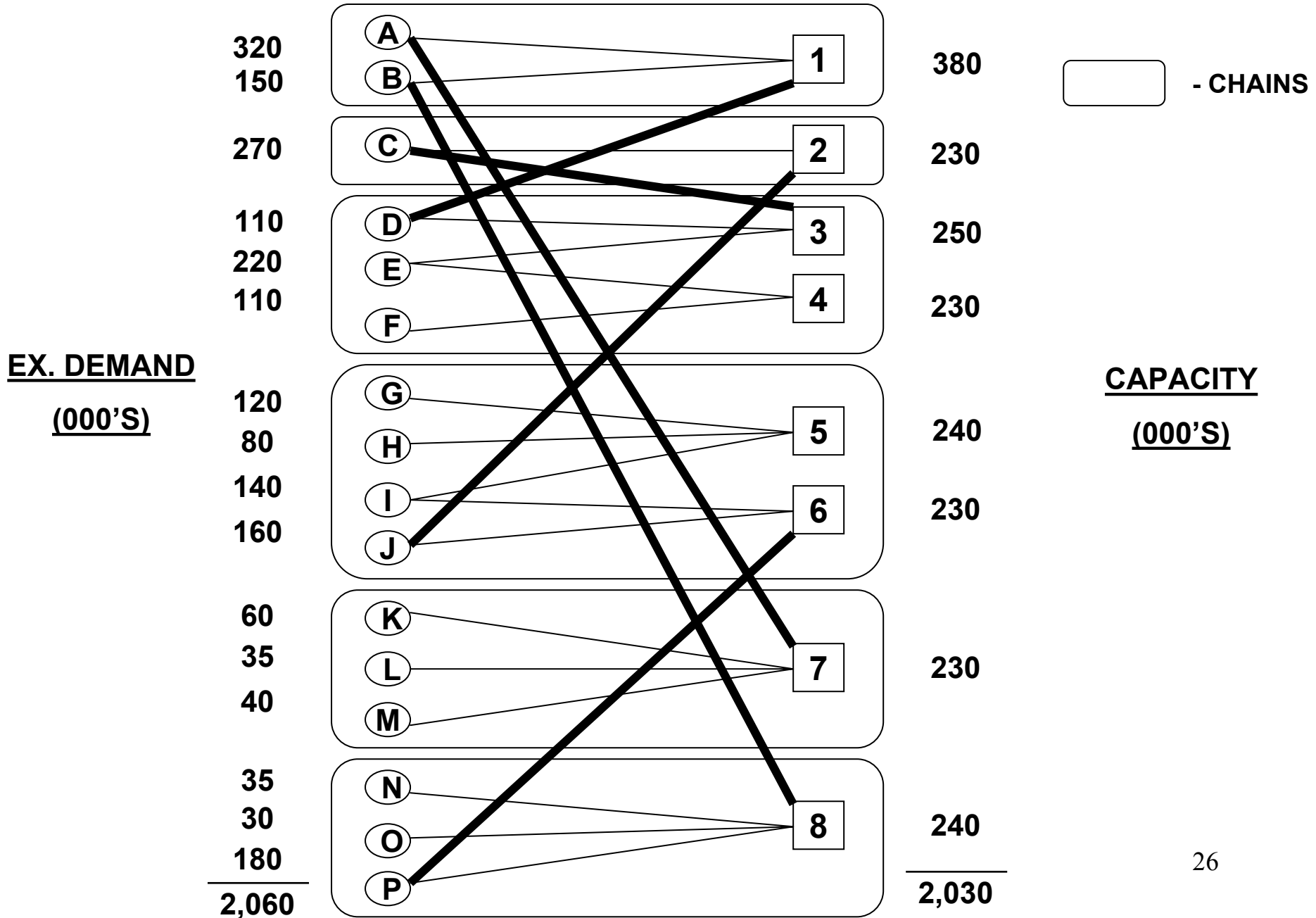


BOC PRODUCT ASSIGNMENT MY 93 PLAN

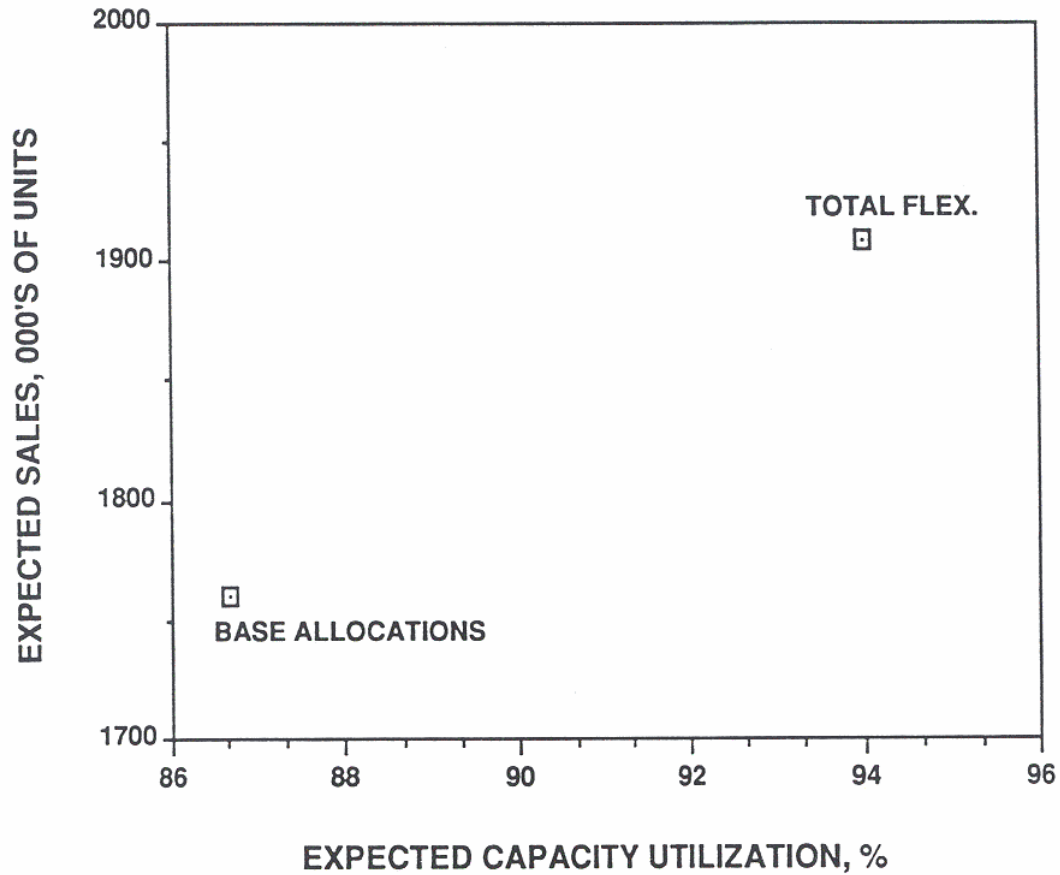


 - CHAIN

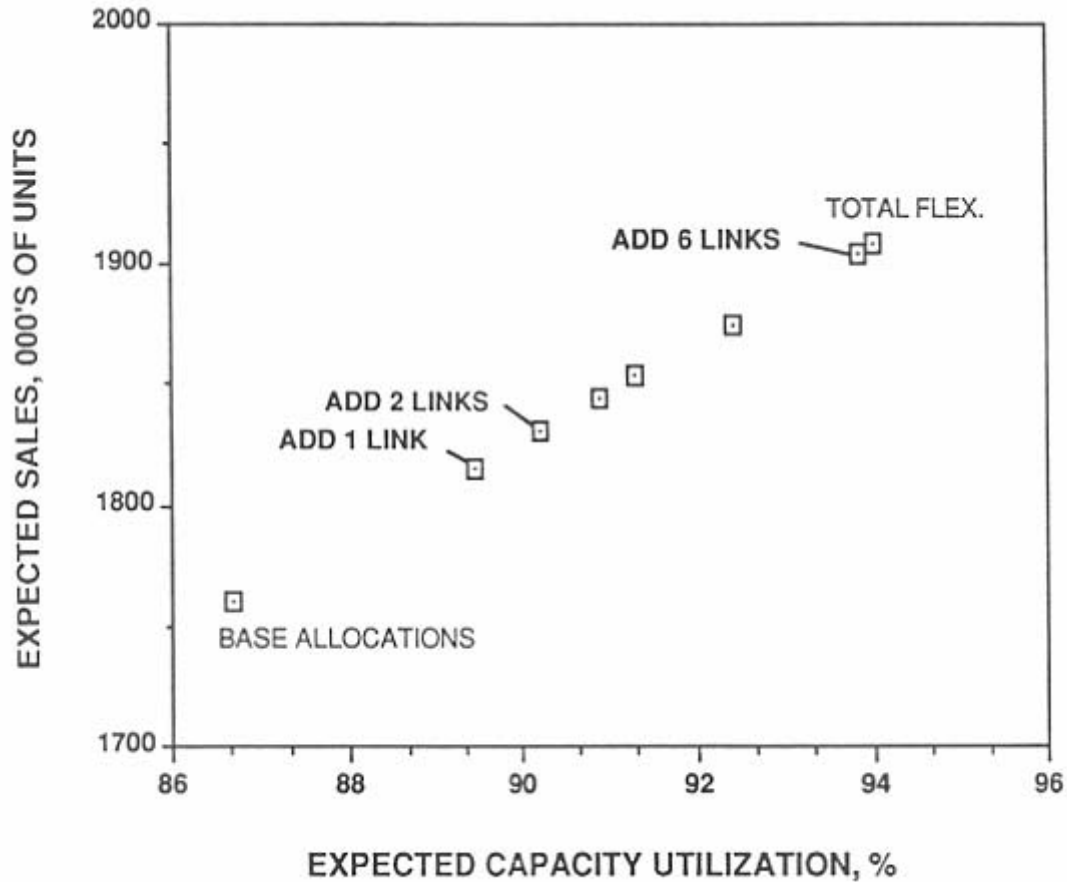
ADD FLEXIBILITY



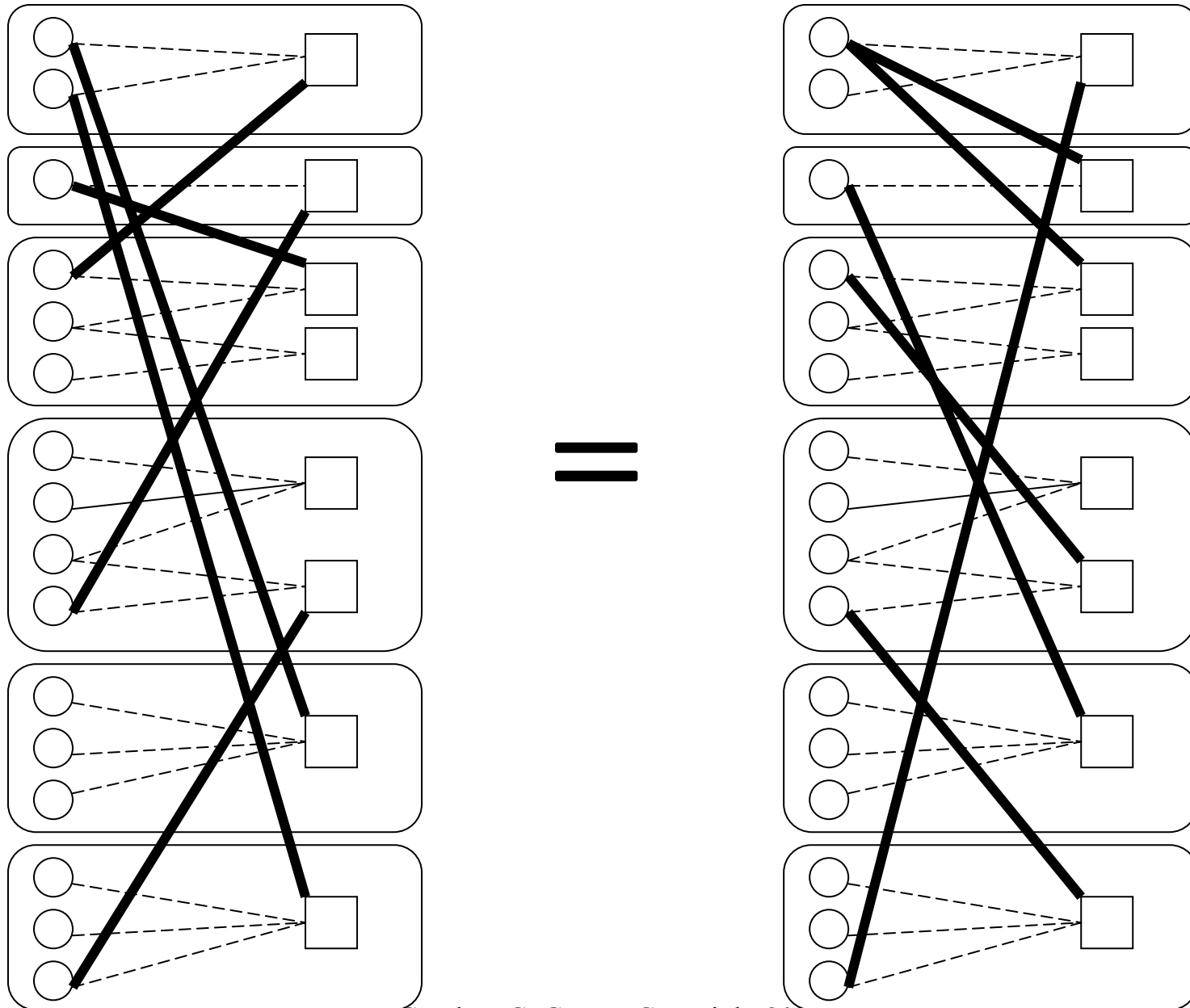
BASE VS. TOTAL FLEXIBILITY



IMPACT OF ADDING FLEXIBILITY



THERE IS NOT ONE "OPTIMAL" FLEX. PLAN



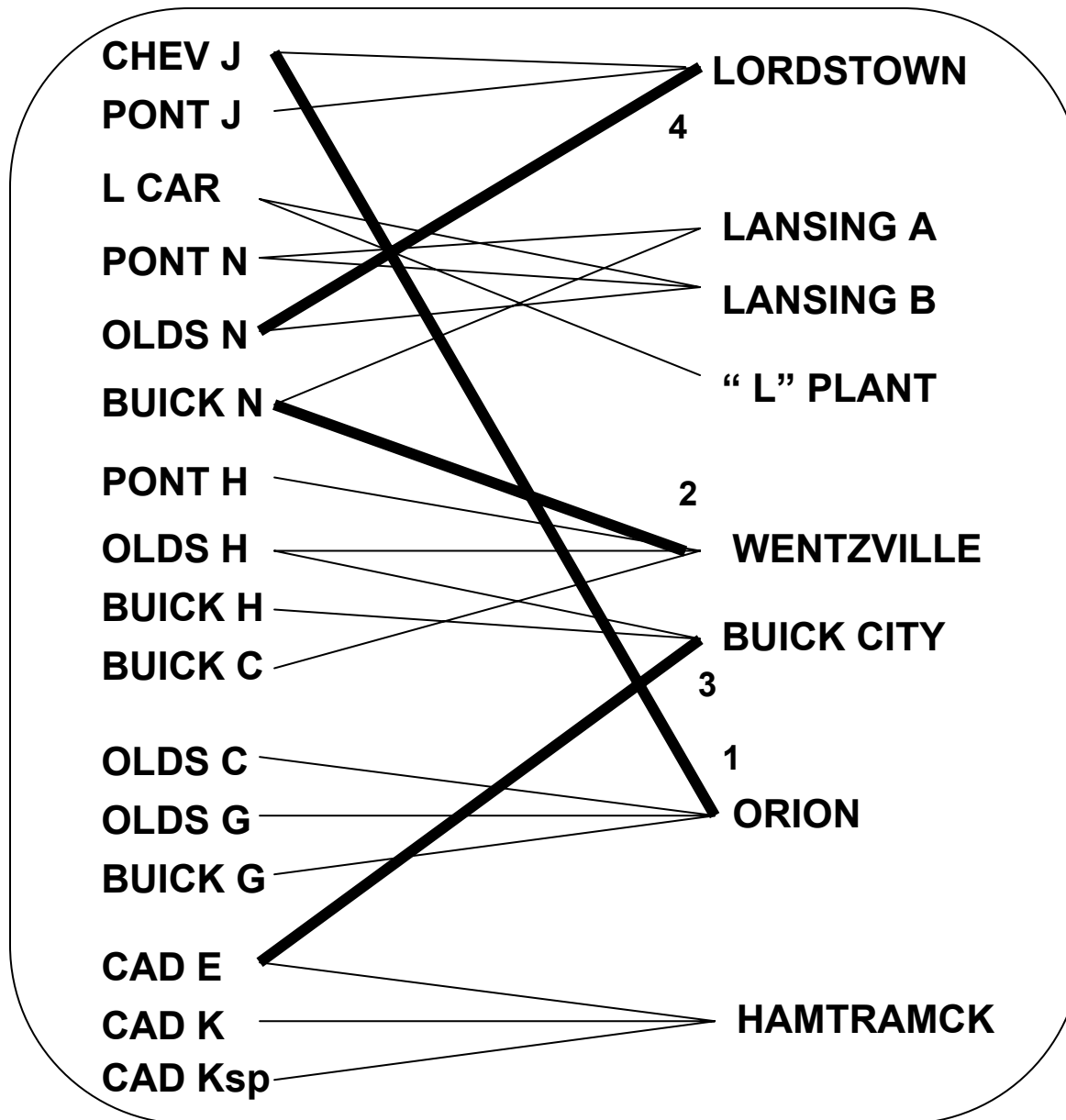
SUMMARY

- **A SMALL AMOUNT OF FLEXIBILITY CAN HAVE MOST OF THE BENEFITS OF TOTAL FLEXIBILITY.**
- **FLEXIBILITY HAS THE GREATEST BENEFITS WHEN ADDED TO YIELD FEWER, LONGER CHAINS.**
- **THERE IS NO SINGLE “OPTIMAL” FLEXIBILITY PLAN; SEVERAL PLANS WILL YIELD THE BENEFITS OF TOTAL FLEXIBILITY**

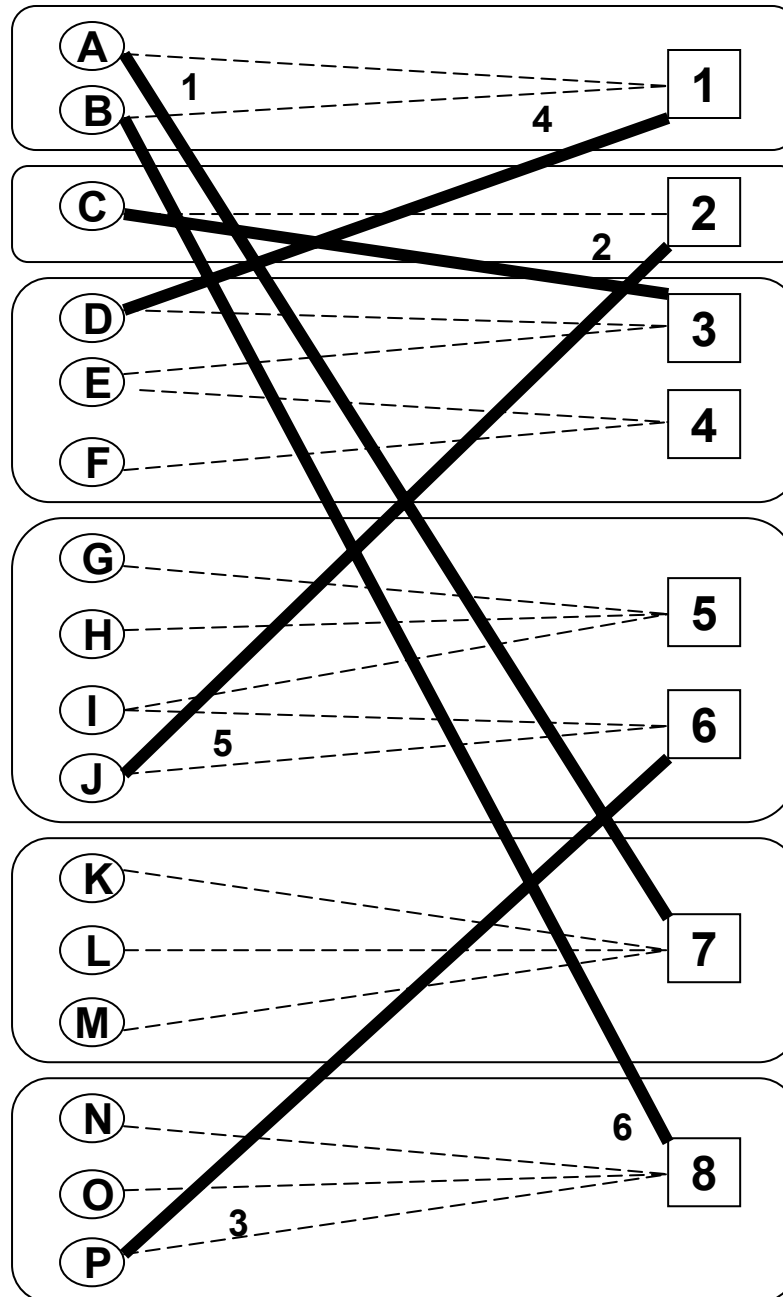
SUMMARY

- **VALUE FROM FRAMEWORK FOR QUANTIFYING BENEFITS OF FLEXIBILITY**
- **FLEX CAP TOOL ALLOWS EXPLORATION OF ALTERNATIVES, AND THEIR EVALUATION UNDER UNCERTAINTY**
- **SUBSEQUENT RESEARCH HAS SHOWN HOW IDEAS EXTEND TO SUPPLY CHAIN, I.E, MULTIPLE STAGES**

EXAMPLE FLEXIBILITY ADDITIONS B-O-C MY 93 PLAN



ADD FLEXIBILITY



Principles

- **Limited flexibility can give you the benefit of total flexibility**
- **Limited flexibility has greatest benefits when create chains**