# TABLE OF CONTENTS

1. So, You Think You Have a Project? .......................................................... 1  
   1.1 Why Use This Methodology? ................................................................. 1  
   1.2 30,000-Foot Overview .................................................................... 2  
2. The 5 Phase Methodology .................................................................. 4  
   2.1 Important Warning ........................................................................ 4  
   2.2 Phase 0—Identifying the Need For Change ....................................... 5  
      - Step 1—Identify Your Real Task at Hand ....................................... 6  
      - Step 2—Gain Some Support ............................................................ 6  
      - Step 3—Develop a Sensible Team .................................................. 7  
      - Step 4—Define Your Goals for this Project ................................... 7  
      Phase 0 Summary ............................................................................ 9  
   2.3 Phase 1—Analysis ............................................................................ 10  
      - Step 1—Identify the Constraints .................................................... 10  
      - Step 2—Establish Solution Design Priorities ................................ 11  
      - Step 3—Define the General Material Flow of Your Business ........ 13  
      - Step 4—Define the General Information Flow of Your Business ...... 14  
      - Step 5—Data Collection and Analysis ............................................ 15  
      - Step 6—Establish a Practical Design Horizon .................................. 17  
      - Step 7—Forecast Future Activity ................................................... 18  
      - Step 8—Concepting ...................................................................... 19  
      Phase 1 Summary ............................................................................ 21  
   2.4 Phase 2—Solution Design ................................................................. 22  
      - Step 1—Develop Performance Specification .................................. 22  
      - Step 2—Document Material Flow ................................................ 23  
      - Step 3—Document the Operation ................................................... 25  
      - Step 4—Technology Selection ....................................................... 26  
      - Step 5—Layout ............................................................................ 32  
      - Step 6—Define the Control Architecture ....................................... 36  
      - Step 7—Simulation ...................................................................... 37  
      - Step 8—Consider General Construction (GC) ............................... 39  
      - Step 9—Schedule Development .................................................... 40  
      - Step 10—Return on Investment Analysis ....................................... 41  
      Phase 2 Summary ............................................................................ 43  
   2.5 Phase 5—Managing the Results ...................................................... 44  
   Phase 5 Summary ............................................................................ 47  
3. The Design-Build Business Model ....................................................... 48  
   3.1 The Guiding Principles .................................................................. 48  
   3.2 The Benefits ................................................................................ 49
1. So, You Think You Have a Project?

You may even have some clever name for it by now, like “The 2006 Robotic Palletizer Initiative,” or “The DC of the Future,” or “The Project Fred Did Before He Retired Project.” In any case, whatever you are considering undertaking, think of it not as a physical task, but a process to impart positive change into the company you work for.

Since 1969, HK Systems has been instrumental in thousands of large and small material handling projects. Over that time, our refined practical design methodology ensures that projects make sense, go well, and deliver at least the results that are expected. In other words, let us make sure that the change realized is in fact, positive.

1.1 Why Use This Methodology?

The process that HK Systems, Inc. (HK) has developed is a simple but effective 5 Phase program that takes a motivated client from concept to ownership. The process has been created with the following attributes in mind:

- **Scalable**—Your project may include adding 25 feet of conveyor to an existing warehouse or it may be the development of a 2 million square foot automated e-fulfillment DC. This process can be scaled for a broad continuum of size and complexity.

- **Practical**—There is no single right answer when conducting design. The levels of fit depend on your company culture, your customers, and your economy. This process flexes to accommodate those variables.

- **Recyclable**—This process has a beginning but no end. It is intended to be an ongoing, dynamic part of your operation. It will continue to serve your company as you later refine your cost of ownership, consider modernizations, and remission your assets for changes in your business.

*This process has successfully been employed with many blue chip icons such as …*
1.2 30,000-Foot Overview

The following graphic illustrates the phases involved in the overall project process, the activities in each phase, and the deliverables that can be expected from each phase. Again, the process that HK follows is scalable and flexible and not all activities are needed for each and every project. The design efforts (in the dashed red boxes) are part of this overall change process.

The Change Process

DESIGN BUILD

On a macro scale, this project process is often referred to as Design-Build; the lockstep process of seamlessly developing and implementing a solution. Design-Build also implies a business model between the Owner and the Integration Partner. The features and benefits of Design-Build are highlighted in a later chapter.
The phases of the process are as follows:

0. **Phase 0—Realize the Need for Change.**
   The Owner has a mathematical, physical, or emotional epiphany that a project is worth considering.

1. **Phase 1—Analysis**
   This preliminary stage, often referred to as the Feasibility Study or Concept Study, is where the business case is generally defined; one or more reasonable approaches are also identified.

2. **Phase 2—Solution Design**
   This design engineering phase involves the refinement of one best-fit solution that has both technical and business merit.

3. **Phase 3—Engineering**
   Multiple disciplines perform the detailed engineering of the designed solution. This often involves manufacturing, software, mechanical, CAD, electrical controls, and systems engineering.

4. **Phase 4—Implementation**
   This phase is the actual delivery, installation, test, and launch of the best-fit solution that was designed.

5. **Phase 5—Management**
   Being a good parent of technology means both care and feeding as well as keeping things current (which requires a sort of design effort in itself).
2. The 5 Phase Methodology

This Design Methodology document will focus on Phases 0 through 2 and the redesign aspects of Phase 5. This document will dissect this 5-phase program to allow better understanding of how to move from a bright idea to enjoying the rewards of technology.

Following is the step-by-step process that we have continuously refined over the last 30+ years, taking clients from need to reward.

2.1 Important Warning

This will not be easy. Designing, deploying and operating effective technological solutions involves several unavoidable requirements from the future Owner:

- **Passion**—Change, when warranted, is often met with fear and requires overcoming corporate inertia. Companies that do not have passion for project success somewhere at all levels will probably end up with a watered down project and watered down results.

- **Talent**—This process requires collaborative expertise. It is not a Things-to-Do list for HK Systems alone; rather, it is a roadmap for partnership and iterative design. You are the experts of your business and we are the experts in design and delivery. Only together will this process be successful. Plan to dedicate various resources to this process.

- **Funding**—The process in this book is about design engineering. Each step in this process requires labor, resources, and travel. Many funding models exist to equitably account for these costs, but be aware that they never really go away. Oh, by the way, skipping steps is not a good way to reduce cost.

Still reading? Good, because it is worth it. In most cases, applying appropriate technology more than pays back the Investor/Owner. When it will not, this methodology will send up red flags and suggest a reevaluation.
2.2 Phase 0—Identifying the Need For Change

OK, we lied. This is actually a 6 Phase methodology but Phase 0 is conducted by you, the Owner. This step involves the internal realization that some sort of change is warranted or at least merits investigation. This need for change can come from one of three general areas in your supply chain:

1. Supply
2. Demand
3. You

THE SOURCE OF REALIZATION

- **Supply Side Requirements**
  - EDI
  - JIT
  - Volume Discounts
  - Technology Demands

- **Demand Side Requirements**
  - Can’t Meet Demand
  - Can’t Make Quality
  - Losing Market Share
  - Losing Profits
  - Technology Demands
  - e-commerce
  - RFID

- **You**
  - Gut
  - Data
  - Experience
  - Standards
  - Directives
  - Regulations

Regardless of where the original thought of change came from, there are several steps that need to be followed during this phase before embarking on detailed analysis.
Step 1—Identify Your Real Task at Hand

The person who is tasked with investigating a project or leading a potential investment, is not responsible for delivering a project to the company. They are responsible for spending the company’s money wisely. Your objective is wise application of company resources. You need to be willing to walk away if this methodology uncovers that the project just does not make sense.

It is critical that whatever you do, the efforts of this process support your company’s core corporate objectives. Typically, those objectives boil down somehow to Shareholder Value and Customer Service.

Step 2—Gain Some Support

This effort will only succeed if you, the Owner-champion, establish executive sponsorship high enough in the company to make sure future efforts will be well spent. Here are some duties to consider:

- Identify the affected and involved and gain support. Namely:
  - Senior Management/The Economic Buyer…involved
  - The Current or Future Owner….affected
  - Technology Partners….involved
  - The Customer(s)….affected
- Provide data to supplement your gut. Management responds better to numeric evidence than to “I really think this will be good for us.”
- Leverage:
  - Fear of competitive disadvantage; is the competition passing you by?
  - Worst case scenarios; what could go wrong without this project?
  - Guilt by association; “now that you know about this issue…”
- Maintain your position as an agnostic soldier
Step 3—Develop a Sensible Team

This step depends greatly on the size and culture of your company, but is critical to your success. Here, you as the Owner-champion establish internal momentum, buy-in, and enthusiasm from the people that will be involved in the project as well as those who will go on to own and operate what you are investigating. A typical internal design support team, and associated responsibilities may look like this:

TYPICAL INTERNAL PROJECT DESIGN TEAM

- Champion
  - You?
- Accomplished Poors
  - Proof of Concept

- 3rd Party Experts (Integrators) (Consultants)
  - Design work
  - Calibrate expectations
  - Experience

- Benefactors (Users)
  - Validate the need
  - Define operational expectations
  - Define ROI

- Executive Sponsor (CXO) (VP of ???)
  - Define success metrics
  - Emotional support
  - Define ROI

- Technology Adopters (Engineering) (IT)
  - Assure corporate compliance
  - Establish cost of ownership data
  - Approval coaching
  - Buy-in

- Supplier Community
- Customers
- Shareholders
- Maintenance

Step 4—Define Your Goals for this Project

This step seems academic but is critical to all future steps. Your team needs to agree on what the real reasons are for considering this project and then drive all efforts to achieving them. More (and even more powerful) benefits may emerge throughout the process, but these foundation goals are your project fight song! Make them measurable. Next are some worth considering and quantifying:
CANDIDATE PROJECT GOALS

(Grade these as: 1=Top Priority 2=Nice to Have 3=Not Interested)

- Elimination of existing unsupportable equipment/control
- Accommodate new product, product envelope, handling requirement
- Reduce personnel direct costs and indirect costs by _____ %
- Reduce customer order response time by _____ %
- Forecasted capacity changes _____ % in _____ Years
- Meet new customer requirements
- Reduce cost of material handling as a % of product cost by _____ %
- Ensure customer service levels defined by Client
- Exceed rate of return levels established by Client—Current_____ % Target_____ %
- Increase shipping capacity by _____ %
- Changing order profile (size, SKUs, quantity)
- Minimize material/employee travel distances by _____%
- Minimize the times materials are picked up or put-down by _____%
- Improve work force scheduling and manpower utilization
- Develop strategies to handle order fulfillment variations
- Improve picking processing time by _____ %
- Increase storage density by _____ %
- Improve access to inventory
- Recover existing floor space for other use _____ sq ft or _____ %
- Recover overhead space for other use _____ sq ft or _____ %
- Reduce storage honeycombing _____ sq ft or _____ %
- Eliminate outside storage
- Expanded storage capacity _____ sq ft or _____ %
- Reduce inventory levels by _____ sq ft or _____ %
- Improve inventory accuracy—Current_____ % Target_____ %
- Eliminate physical inventories
- Reduce inventory aging—Current average _____ days, Target _____ days.
- Increase inventory turns _____ per _____
- Maximize FIFO
- Meet customer EDI requirements
- Eliminate/reduce paperwork
- Improve timeliness and accuracy of information
- Improve order accuracy—Current _____ %, Target _____
- Improved visibility to internal and external members of your supply chain
- Added/improved connectivity with collaborative partners in or outside the enterprise
- Minimize delays due to data entry, induction, location assignment, material tracking
- Integrate RFID for reasons of customer compliance requirements
- Integrate RFID for reasons of process improvement
- Reduce/Eliminate Pilferage and/or Increase Inventory Security
- Increase Inventory Environment Quality i.e.—reduce product damage
  Current % of product damaged_______ Target ________
Phase 0 Summary

The objective of Phase 0 is gaining the approval and confidence to conduct the Analysis Phase.

The deliverables from this phase are:

- Confidence that change is warranted
- A passion to improve your business
- Management’s commitment
- An established working team committed to the company’s core objectives

Here are the key take-aways from Phase 0:

- Secure executive sponsorship so later you are not disappointed.
- Clearly define and never lose sight of your real, measurable project goals.
- Make sure the project goals support the company’s core corporate objectives.
- Involve a pragmatic team that assures universal perspective and buy-in.
2.3 Phase 1—Analysis

This phase is often referred to as a *Feasibility Study* or *Concept Study*. In short, it is the process of evaluating a company’s business, material flow, operational data, and identifying opportunities for improvement. Ideally, these opportunities support the goals identified in the prior phase.

There are countless products and practices available to move, store, and ship material. If you are in doubt, just go to Promat with a roll of drawings under your arm and see how you immediately become popular. (Promat is an annual trade show of the material handling industry.) The point of Phase 1 is to efficiently narrow your options to a practical set of alternatives that make sense for your company.

**IDENTIFY YOUR TARGET SOLUTION**

- **Step 1—Identify the Constraints**

  The first thing to do is to rally your executive and operational teams and define the **must haves** and the **don’t wants**. These are the project constraints and there is no sense in going down those roads if they are not acceptable. Note however, that if constraints are raised that you feel are prohibitive to the success or viability of the project and its goals, this is your last chance to challenge them.
Some examples of constraints are:

- **Budget** “Board will never spend more than $4.5M”
- **Space** “Must fit in owned property”
- **Schedule** “Need to be up before seasonal peak”
- **Labor** “Impossible to find loyal work force”
- **Environment** “-20F freezer not fit for humans”
- **ROI** “Must pay back in no more than 26 months”

This effort will make the future steps and phases much more efficient.

**REDUCE ALTERNATIVES THROUGH CONSTRAINTS IDENTIFICATION**

Eliminate the options that are out of the question. Move to narrowed options.

- **Step 2—Establish Solution Design Priorities**

Earlier, we defined the project objectives and then narrowed our solution paths through constraint identification. Now, we will further narrow our alternatives by defining the guiding principles of the design process. These are both business issues and technology issues but in either case, come from the culture and mission of your company. The list below is a sample of design considerations to evaluate.
SOLUTION DESIGN PRIORITIES

(Grade each of these from 1-10, 1=Top Priority, 10=Lowest Priority)

- Minimize staffing and material handling, maximize automation
- Minimize overall project costs to meet the minimum defined budget
- Financial return on investment ROI: _____ % or Payback in ______ years.
- Minimize the overall facility/system footprint Target _____ sq ft
- High level of fault tolerance/redundancy wherever possible
- Apply only highly proven technologies and practices to minimize risk
- Apply state of the art technology that will remain current for ______ years.
- Focus on cosmetics and appearance of the solution
- The system solution should not require changes to the remainder of the operation
- Solutions that are re-configurable for operational flexibility, new products, processes.
- Solutions that are expandable for future growth _____ % growth in ______ years.
- Maximize commonality of technologies to simplify parts and service requirements.
- Provide low risk approach to implementation with minimal interruption to operation
- Compliance to defined corporate standards for project design, technology, standards
- Minimize number of suppliers involved, i.e. Turn-Key solution by one supplier
- Minimize Implementation Schedule—Target ______
- Avoidance of a particular technology—Specifically________________________
Step 3—Define the General Material Flow of Your Business

Here, we capture and study the way material moves in, through, and out of the area we are contemplating affecting. It is best to understand what is done today and identify any known changes to the business model that are planned for the future and worth considering in the design. This is not intended to be a detailed material flow diagram, but a cursory understanding of how things move from a business perspective.

TYPICAL MATERIAL FLOW OVERVIEW

Most current material flow systems are the product of many years of change and growth, leaving the Owner with an often non-ideal operation. It may be effective but not what would have been designed from scratch. The objectives of this step are to understand how materials move today and identify any opportunities for improvement and applications for current best practices.
Step 4—Define the General Information Flow of Your Business

Overlaying every material movement system is an information system of various levels and complexity. This step involves understanding this virtual network of moving data and any planned changes to elements in the structure.

TYPICAL GENERAL INFORMATION FLOW OVERVIEW

Again, the design team will look for obvious holes, areas of risk, obsolescence, illogical data flow, and the like as a baseline when crafting the new design. Likewise, areas that are defined as givens such as interfaces to enterprise-wide systems will be noted.

Of particular interest at this point are:

- Enterprise Management Systems and future migration plans
- Technology preferences (database, platform, operating systems)
- Networking preferences
- Supply chain partner interfaces and/or visibility
Step 5—Data Collection and Analysis

This vital step requires an in-depth collection and evaluation of current and planned operating data. The data is collected by two means; download of operational data and interviews.

Using extensive, proven data forms, the design team gathers functional information on processes, material movement, material profiles, and much more gleaned from interviews with key personnel.

DATA COLLECTION FORMS

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<tr>
<td>Other</td>
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<tr>
<td>Operating Days Per Week</td>
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<tr>
<td>Operating Hours Per Shift</td>
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<td>Supervision</td>
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<td>Load Putaway</td>
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<tr>
<td>Clerical</td>
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<tr>
<td>Other</td>
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</table>
In addition to functional data, the team will require downloads of live operational data that includes but is not limited to:

- Typical orders processed for a range of activity levels
- Inventory data, segmented where possible
- Item master files, SKU profiles
- Communication logs with neighboring systems

From this data, the team will evaluate the information from many dimensions looking for trends and opportunities that help point to candidate technologies, material flow, and layout.

The resulting analysis is graphed and business observations verified. The client confirms the findings before they influence the design.

**DATA ANALYSIS**

![Cases Picked Per Day (All Stores)](chart1)

![SKU Ranking (Dairy)](chart2)
Step 6—Establish a Practical Design Horizon

The designs that we will consider, their cost and subsequent returns are greatly influenced by the time period the Owner expects them to be relevant. For example, if we design a solution that is expected to serve the Owner for only 2 years, the accuracy of the operating data will be very high but the Return on Investment (ROI) will be poor unless the design is very inexpensive. On the other hand, if we try to design a system that will be serving the Owner for 30 years, it may very well have to be over-designed due to the improbability of good 30-year business forecasts.

As many of us know, vision worsens with age. Find a reasonable design horizon based on:

- Amount and accuracy of historical data to establish reliable operating trends
- Your confidence in future conditions that drive your business

As a rule of thumb, unless you are very close to retirement, base your designs on a 3 to 10 year forecast. Most material handling assets are expected to physically serve their Owners for at least 20 years. However, at the rate business changes, a remissioning or modernization in the 10 year time frame is probable and will assure that the return on your assets remain high for the 2nd 10 years.

**DESIGN HORIZON RANGE**

[Diagram showing accuracy of estimations over a range of years from 3 to 10]
Step 7—Forecast Future Activity

Now that we have established a viable design horizon, we will apply what we know about the business to forecast activity in that time frame. The client team is interviewed to gather input to what range of changes could take place in the established design horizon. The resulting net forecast is not necessarily what we will design to, but rather a best guess at a range of future operating activity. For example:

**EXPECTED ORDER VOLUME INFLUENCES**

![Graph showing expected order volume influences with core business extrapolation, planned acquisition, and expected market down cycle highlighted.](image)
This exercise is conducted for all operating variables to develop a best-possible forecast of activity at our selected design horizon. For example:

- Inventory
  - Level
  - Turns
  - Mix
- Order
  - Volume
  - Mix
  - Source
- Shipping
  - Mode
  - Added Value Operations

Step 8—Concepting

Now that goals have been set, design criteria defined, data analyzed, and a baseline understanding of current and projected operations has been established, the team begins the magic of concepting one or more appropriate solutions. Short of detailed engineering design, this step yields a range of possible configurations that vary in terms of:

- Level of automation/complexity
- Cost
- Return
- Speed of return
- Cost of ownership
- Flexibility

The HK team applies years of experience, best practices with the goals, priorities, and constraints defined with the client to render a continuum of preliminary concepts.
Typical activities and deliverables that take place at this step include:

- Team brainstorming and interactive, iterative design
- Solution sketches
- Applying what-if scenarios
- Developing 3-D animations to bring to life the concept
- Conducting site tours of comparable technologies in action
- Preparing budget pricing
- Preliminary schedules for each option
- Developing a budgetary ROI analysis for each concept

The client then contributes elements such as corporate culture and appetite for technology to provide feedback on the concepts. This prepares HK for the next phase: Detailed Design.
Phase 1 Summary

The objective in Phase 1 is to generate one or more preliminary concepts that support the project and promise to deliver acceptable return to the Owner.

The deliverables from this phase are:

- Operating and functional data compilation and analysis
- Description of planned material flow
- One or more solution concepts including sketches and/or 3-D animations
- Feasibility, pros and cons of each concept
- Budgetary pricing and schedules
- Preliminary ROI analysis
- A cohesive working team with clear objectives and enthusiasm

The key take-aways from Phase 1 are:

- Have a clear understanding of your current material and data flow.
- Be realistic when defining design priorities and constraints.
- Use defendable activity forecasts for a time frame that is realistic in your environment.
2.4 Phase 2—Solution Design

This phase leverages the concept(s), business understanding and the enthusiasm developed in Phase 1 and distills them down to one, best-fit solution based on everything we know at this point.

Once that solution is identified, the engineering details are taken from the concept level (typically referred to as the +/- 20% level) to a final, firm state. The sequence of steps in this phase is important to efficiency and minimizing rework.

- Prerequisite Steps
  1. Develop Performance Specification
  2. Document Material Flow
  3. Create a Description of Operation
  4. Technology Selection
  5. Layout

- Dependent Steps
  6. Design Control Systems
  7. Document Interfaces
  8. Conduct Simulation Modeling
  9. Scope the General Construction
  10. Develop Schedule
  11. Prepare Cost Estimates

- Validation
  12. Conduct Return on Investment Analysis

The deliverables from steps 1-8 are compiled in a comprehensive document called the Detailed System Requirements Specification (DSRS) that becomes the living design document throughout the course of the project and beyond.

- Step 1—Develop Performance Specification

  Throughout the design phase, it is imperative to keep an ever-watchful eye on your cost and ROI relative to your means (budget). Design is an engineering task; however, very few economic courses are required to get an engineering degree. So, be sure not to design something so wonderful that you can not afford it.

  In Phase 1 we defined current and forecasted operating data. Now we need to define where in that range of data we want to design the solution. To design for worst case may not be a prudent use of funds.
Consider factors such as:

- Seasonal peaks
- Cost of periodic 3rd party support
- Cost of periodic increased labor
- Random spikes in business due to promotion

Define what the design sweet spot is in your data set. Do this for all of the operational data that affect the design.

ESTABLISHING DESIGN-TO PERFORMANCE POINTS

It is very probable that the best overall company value lies in designing a solution that accommodates your needs most of the time but not all of the time.

Be sure to consider that the new system operations may level some of the peaks in the data.

- Step 2—Document Material Flow

In this step, we take the general business based material flow analysis and generate a very detailed material flow diagram that will serve as the foundation of our design. Only with a clear understanding of the minimum and maximum rate of flow between areas of the business can we hope to balance the technologies and design at each area.
Following is a sample Material Flow Diagram to illustrate the level of detail achieved. This product later will become the base assumption for the simulation model.

**TYPICAL MATERIAL FLOW DIAGRAM**

Study of this diagram allows the engineers to identify potential bottlenecks, highlight opportunities for improving or consolidating flow, and begin to generate guidelines for technology selection later.
Step 3—Document the Operation

Only with the input from the established client team can we define the operational expectations of the system. It is then HK's job to apply industry best practices and offer alternatives for consideration. The team members each have specific areas to contribute to this process:

TEAM DOCUMENTATION

- What have others done?
- What works/doesn't?
- Current best practices
- What do we do today?
- Where is the business going?
- What don't we like today?
- Wish list of features?
- What are our customers asking for?
- What is our strategic plan?
- What can we afford?
- What is our culture?
- How will this interface?
- What are our standards?
- Can we make it work?
- Can we maintain it?

This can be a daunting task unless it is broken down into manageable dimensions. Our process involves documenting the physical, business, and logical operation in 3 perspectives:

- Material Flow—how does the operation look from the perspective of material moving through it? For example:
  - Receiving
  - Storage
  - WIP
  - QA
  - Cross docking
  - Order fulfillment
  - Shipping
  - Transportation
  - Returns
- Personnel—how does the operation look from the perspective of the people working in it?
  - Efficiency & Effectiveness
  - Ergonomics & Safety
  - Exception handling
  - Added value functions
  - Decision making
  - Travel time, deadheading
  - Data entry activities
  - Accuracy rate requirements

- Information—how does the operation look from the perspective of the data moving through it?
  - Data volumes
  - Visibility in and outside of the facility
  - Reporting requirements
  - Throughput
  - Interfaces (ERP, Sales, WMS, MES)
  - Supply chain partners
  - Security & Validation requirements
  - Recovery measures
  - System management capabilities

**Step 4—Technology Selection**

This is the fun part; identifying the right system, device, control, and practice to best perform a function. Again, we need to first break the operation down into manageable pieces. In this step, we will segment the physical business into definable, functional blocks. Avoid thinking of these as physical areas of your current building (like repack or staging) but rather activities that are required in your company.
Examples of **Functional Blocks** include:

- **Inbound**
  - Receiving
  - Raw Material Storage
  - Depalletizing
- **Order Processing**
  - Cross Docking
  - Piece Picking
  - Order Consolidation
  - Replenishment
  - Forward Pick
  - Added Value Processing
  - Sortation
  - Kitting
  - RFID Compliance
- **Production Logistics**
  - Work In Process Storage
  - Finished Goods Storage
  - Yard Management
  - QA Sampling
- **Outbound**
  - Packaging
    - Palletizing
    - Shipping
    - Transportation Management
- **Material Movement**
  - Inbound
  - Inter-system
  - Outbound
- **Returns Processing**

Next, we will evaluate each Functional Block on its own and conduct these efforts:

1. Define the options that fit within the stated **priorities** and **constraints**.
2. Quantify the costs and rewards of each option
3. Determine best fit option
For example, consider the functional block of Material Movement, specifically pallet movement. Several technology options exist. However, if one of our constraints is that quality, affordable labor is unavailable in our area, we may have to first eliminate manual based options (fork trucks).

EXAMPLE PALLET TRANSPORTATION OPTIONS

Next, we quantify the costs and returns of each and apply the project priorities.

EVALUATING THE REMAINING OPTIONS

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>COST</th>
<th>PROS</th>
<th>CONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated Guided Vehicles</td>
<td>$700,000</td>
<td>Flexible path, built in redundancy, easy to add capacity (vehicles)</td>
<td>Need battery management, computer</td>
</tr>
<tr>
<td>Automated Monorail</td>
<td>$1,200,000</td>
<td>No floor space occupied, can add capacity (carriers)</td>
<td>Requires structural ties to building steel, need computer</td>
</tr>
<tr>
<td>Conveyor</td>
<td>$550,000</td>
<td>Low Cost, reliable, only PLC control</td>
<td>Occupies floor space, fixed asset, no redundancy</td>
</tr>
</tbody>
</table>
In this example, if cost is the #1 priority, conveyor may be the choice. However if flexibility is key and space is limited, AGVs may be the best-fit solution for this block.

It is apparent for each Functional Block that there will exist several candidate technologies, ranging from simple/manual to sophisticated/automated. When applied appropriately, the more automated usually have a greater net return but they are not for everyone. For example, in the Functional Block of pallet storage, there exists a range of options.

**EXAMPLE TECHNOLOGY CONTINUUM**

<table>
<thead>
<tr>
<th>Automation/Complexity</th>
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<tbody>
<tr>
<td>Function Block</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>Medium</td>
</tr>
<tr>
<td>High</td>
</tr>
</tbody>
</table>

- **Storage**
- **RF-Based Manual**
- **Automated VNA Trucks**
- **High-bay ASRS**
A good exercise to conduct during this Technology Selection step is to determine the **automation-readiness** of your company. Automation offers several tangible rewards for the user who is committed to harvesting them. See if these match any of your Project Goals:

**The Rewards of Automation**

- **Operational Savings**
  - **Labor**
    - Elimination of conventional machine labor
    - Improved efficiency of personnel
    - Consistent performance
    - Reduction of ergonomic issues
  - **Product**
    - Minimal product damage with precision handling
    - Predictable product rotation and aging
    - Can add value to product
  - **Assets**
    - Smaller footprint of facility
    - Cost of ownership

- **Overcoming Environmental Challenges such as**
  - **Temperature**
    - Performs 100% effectively and efficiently in wide temperature range
  - **Hazardous**
    - Operates in unfriendly environments (nuclear, chemical, caustic)

- **Providing Increased Functionality to the Owner**
  - **Inventory Accuracy**
    - 100% computer controlled material movement
    - Elimination of physical inventories
  - **Inventory Optimization**
    - Automated velocity zoning based on turn rate
    - Reduce on-hand inventories
    - Maximum use of space
  - **Physical Flexibility**
    - JIT delivery of sequenced product to shipping or production

- **Offering High Levels of Security**
  - **Physical**
    - Preventing access to valuable inventory
  - **Logical**
    - 100% tracking of all transactions and inquiries
    - Flexible alarm monitor system to annunciate any or all transactions
  - **Preventative**
    - Fire and Smoke protection
For each Functional Block we will independently consider the continuum of potential technologies, filter them with the priorities and constraints, and make a preliminary selection based on fit and ROI. (More on how to conduct the ROI evaluation later!)

### SAMPLE TECHNOLOGY CHART

<table>
<thead>
<tr>
<th>Function Block</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiving</td>
<td>Paper manifest</td>
<td>RF directed expected receipts</td>
<td>RFID</td>
</tr>
<tr>
<td>Raw material storage</td>
<td>Fork truck to static rack, pushback rack, drive through rack</td>
<td>Carousel, vertical storage module, automated forklifts</td>
<td>High-bay ASRS, deep lane density storage</td>
</tr>
<tr>
<td>Depalletizing</td>
<td>Manual</td>
<td>Automated layer depalletizers</td>
<td>Robotic</td>
</tr>
<tr>
<td>Transportation</td>
<td>Fork truck, cart</td>
<td>RF directed fork truck, tow line, power &amp; free conveyor, tugger AGV</td>
<td>Automated guided vehicle, conveyor, automated electrified monorail, pneumatic tube</td>
</tr>
<tr>
<td>Place picking</td>
<td>Pick to paper</td>
<td>Smart cart, RF directed pick-to-belt/tote/case, pick-to-light</td>
<td>A-frame, in-rack, ASRS, picking, robotic</td>
</tr>
<tr>
<td>Order consolidation</td>
<td>Manual marshalling</td>
<td>Put-to-light</td>
<td>In-storage automated order build</td>
</tr>
<tr>
<td>Replenishment</td>
<td>Fork truck, cart</td>
<td>Tugger/AGV/RF directed delivery to pick zones</td>
<td>ASRS to flow rack</td>
</tr>
<tr>
<td>Added value processing</td>
<td>Manual exception handling</td>
<td>Automated exception handling</td>
<td>Preemptive automated diversion</td>
</tr>
<tr>
<td>Sortation</td>
<td>Manual product diversion</td>
<td>Conveyor pushers</td>
<td>Sliding shoe, cross belt, JIT tray</td>
</tr>
<tr>
<td>Kitting</td>
<td>On-floor marshalling</td>
<td>Pick-to-build</td>
<td>JIT in-storage kit building</td>
</tr>
<tr>
<td>Work in process storage</td>
<td>Fork truck to static rack, pushback rack, drive through rack</td>
<td>Carousel, vertical storage module, automated forklifts</td>
<td>High-bay ASRS, deep lane density storage, use point managers in manufacturing</td>
</tr>
<tr>
<td>Finished goods storage</td>
<td>Fork truck to static rack, pushback rack, drive through rack</td>
<td>Carousel, vertical storage module, automated forklifts</td>
<td>High-bay ASRS, deep lane high density storage</td>
</tr>
<tr>
<td>Yard management</td>
<td>Paper</td>
<td>RF directed</td>
<td>RFID directed, GPS, UWB</td>
</tr>
<tr>
<td>Packaging</td>
<td>Post-picking, manual</td>
<td>Pick-to-package</td>
<td>Robotic fill, close and label</td>
</tr>
<tr>
<td>Palletizing</td>
<td>Manual</td>
<td>Automated layer palletizers</td>
<td>Robotic</td>
</tr>
<tr>
<td>Shipping</td>
<td>Manual</td>
<td>Extendable conveyors</td>
<td>Automated truck loading</td>
</tr>
<tr>
<td>Transportation</td>
<td>Paper</td>
<td>Generic TMS</td>
<td>Multi-carrier TMS</td>
</tr>
<tr>
<td>Return processing</td>
<td>Exception handling</td>
<td>As part of WMS</td>
<td>Dedicated returns management system</td>
</tr>
</tbody>
</table>
Next, we evaluate **all** the Function Blocks as a **whole** for added efficiencies and function consolidation. For example:

- Can WIP, Raw Material, and Finished Goods all share the same warehouse?
- Can the same AGV system that delivers to manufacturing load trucks?
- Can we mezzanine the RFID operation over shipping to reduce delivery time?
- Can the added value function be done at the time of picking via RF direction?

At this point, we should have a solid selection of technologies that fit the objectives and constraints of the Owner and are prepared to orient them in an optimally efficient layout.

> **Step 5—Layout**

The process of laying out a piece of equipment, system, or facility is an iterative process. There is no one optimum solution but your hope is to concentrically narrow onto a very good solution. The general process follows:

**LAYOUT PROCESS**
This is a very good time to revisit the Solution Design Priorities that we generated earlier. Many of these will help frame the way the solution is oriented. Typical priorities are listed below and often conflict with each other. So, be clear on yours!

- Minimize footprint
- Allow for maximum future flexibility
- Allow for future expansion
- Minimize interaction between personnel and automation
- Allow plenty of dock space
- Minimize travel distances

The first task in orienting the components or subsystems is to identify the givens. What are the aspects of the environment that will drive the way equipment or material flow is oriented? As shown in the following illustration of a new facility layout, these drivers can be business related, legal, geological, or geographic.

IDENTIFYING DESIGN GIVENS
Next, begin the creative task of morphing your technology selection to your material flow diagram and generating a flexible and efficient layout. This activity tends to be done using two-dimensional mediums like a whiteboard and desktop but spatial opportunities can be missed. So, be sure to think in 3-D to maximize space utilization. Consider:

- Mezzanines
- Conveyors that incline and decline around assets
- Overhead conveyance or monorail
- Underground transportation & storage

DESIGNING IN 3-D
Following is a high level example of the layout process:

DEFINE PHYSICAL GIVENS

LOGICALLY ORIENT SELECTED TECHNOLOGIES

APPLY TO-SCALE COMPONENTS
Step 6—Define the Control Architecture

This step needs to progress somewhat concurrently with technology selection and layout since they are interdependent. Here, the electrical controls and software engineering teams at HK meet with the IT and technology leaders of the client company and design the bottom-to-top control systems that will overlay the solution.

Here are some of the tasks involved:

- Determine what corporate standards exist and to what level they need to be complied with, such as:
  - Platform
  - Licenses
- Define the levels of control; what number and types of systems will manage this solution and business (see illustration)
- Establish responsibilities of each. Often, multiple systems in an architecture have the built-in functionality to offer a service, the team needs to decide where it is most logically performed with the least risk and greatest strength. Examples include:
  - Data keeping
  - Diagnostics
  - Business rules
  - Workforce accountability
- Select connectivity; this includes both the physical and soft methods of connecting systems such as networks and protocols
  - A detailed System Interface Specification is generated
- Define Success—what testing will be conducted at what points in the project and what will be the agreed-upon levels of achievement at each point.
  - In-house unit test
  - Emulation system testing
  - Functional test
  - Throughput test
The resulting hardware architecture overview often looks like this:

**TYPICAL CONTROL ARCHITECTURE DIAGRAM**

---

So, you are feeling pretty good at this point. However, before we start cutting ribbons, we need to conduct a virtual test of our design using simulation modeling. This imperative process employs a 3-D computer generated model to simulate the material flow, equipment response, control logic, and personnel in the planned system.

**ELEMENTS OF A SIMULATION MODEL**

- **Animation**
- **Layout & Material Flow**
- **Equipment Response**
- **Control Logic**
- **Data Variables**

---

**Step 7—Simulation**

So, you are feeling pretty good at this point. However, before we start cutting ribbons, we need to conduct a virtual test of our design using simulation modeling. This imperative process employs a 3-D computer generated model to simulate the material flow, equipment response, control logic, and personnel in the planned system.
A simulation model allows us to evaluate multiple designs, quantify precise throughput capability of a design, view the system in action prior to construction, identify bottlenecks, and balance design elements. It is also a great tool to bring to life a planned solution for a prospective Owner and allow them to compare the vision to what they know are the real business parameters.

A simulation model is not just for large projects. A model can be generated and is helpful at various levels of operation:

- A person
- A machine
- A system
- A facility
- A supply chain

SIMULATION IMAGE

Once a model is complete and validated, Sensitivity Testing takes place to see how reactive the solution is to changes in operating data and issues.
Step 8—Consider General Construction (GC)

If this project is of a magnitude to include a new building and/or modifications to existing buildings, we will now consider how that effort is impacted by the material handling design. This step is often disregarded as unrelated to designing a solution but in fact can be critical to the success and cost containment of a new system. A building that surrounds an integrated material handling system is usually a part of that system, not a simple structure. Following are some of the GC considerations that are interrelated to the system design:

GENERAL CONSTRUCTION DESIGN CONSIDERATIONS

The result of this step may be refinements to the layout and a list of foresighted building design elements that will ultimately make the facility more effective and less expensive.
Step 9—Schedule Development

With the scope clearly defined at this point, the project schedule will be created. This schedule will drive the staffing plan and subsequently the cost and ROI of the project. Schedules also set the expectations of Owners and benefactors as far as when they will realize the rewards of their investment. This step needs to be well founded. Here are some notable guidelines based on many years of experience.

- The later you realize the reward, the later your ROI starts.
- It is better to apologize for a long schedule than an overrun schedule.
- Nothing is more accurate than history; collect data from veterans.
- Contingency is not for mistakes, it is for the unplanned probables.
- Most humans are optimists.

Schedules are delivered at two levels, a top-line milestone summary level and a detailed Microsoft Project level showing interdependencies.

### TYPICAL SUMMARY LEVEL SCHEDULE

<table>
<thead>
<tr>
<th>PHASE</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
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<th>JUN</th>
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<td>Bid Q&amp;A, Site Tours, References, Rebids</td>
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Step 10—Return on Investment Analysis

This step is conducted in a cursory fashion at the functional block level and now we will perform a detailed ROI calculation for the entire project. The process conducted is not just a determination of what a project will cost and pay back, but a thorough 10-year cash flow comparison of two scenarios. The activities involved in a comprehensive ROI analysis are:

A) Classify the project—First determine if this is a project that will be judged based purely on financial return—does this project have other intangible drivers such as customer demands, safety, and obsolescence. This may make ROI study less important.

B) Define the planning horizon—As we did for the design phase, agree on what time frame we have supportable cash flow data and what the realistic life of the solution will be.

C) Specify the alternatives—Here we clearly document what 2 scenarios we are going to compare, such as “buy a robotic palletizer” or “hire 3 more full time employees.”

D) Estimate the cash flows for each alternative—This involves detailed quantifying of all direct and indirect costs and incremental revenues over time for each alternative.

E) Specify the interest rate—The current cost of money in your company will have an impact on the results.

F) Compare the alternatives—There may be more than 2 potential scenarios to consider. Run this model for various pairs of alternatives, always keeping constant one base case scenario to assure accuracy.

G) Perform sensitivity analysis—Once the results are generated, adjust the variables that you feel are likely to change over time and see if any of them have an inordinate effect on the outcome.

H) Select the best alternative—Best may be defined in many ways, depending on your company’s requirements. Consider internal rate of return, time to pay back, net cash flow, and percent ROI.

I) Check your results—Finally, ask yourself if the results make sense based on your experience. Then, determine if the results will match the objectives that were established early in the design process.
VALIDATE THE OUTPUT

The business tool that HK Systems uses to conduct this analysis is a simple but comprehensive worksheet based on a large database of automated project scenarios. An extensive list of potential cash flow considerations prompts the user to think about non-obvious sources of expense and income, both tangible and intangible, over a 10-year period. The tool then generates annual summary data in both today’s dollars and with consideration to inflation.

ROI TOOL OVERVIEW

The tool also provides various levels of results to quantify the net value of the investment to the company.
ROI analysis is not the final answer to whether or not a project is viable; it is another step in the iterative design process. If the ROI analysis produces unfavorable results, be glad you ran the test and rework the design to produce a higher overall value.

Phase 2 Summary

The objective of Phase 2 is to generate a single best-fit solution for the project proposed. It also adds the level of detail sufficient to define the components, cost, schedule, and finally, establish an ROI that justifies the investment.

The deliverables from Phase 2 are:

- A Detailed System Requirements Specification (DSRS) describing the components of the solution, a description of operation, and a control architecture
- Material flow diagrams
- Layout and functional drawings
- A 3-D graphical and statistical simulation model
- An ROI analysis
- A firm price and schedule

Key take-aways from this phase are:

- Design is an iterative and collaborative process.
- Establish goals, constraints, and operations before jumping to solutions.
- Plan for a time period that your business can rationalize.
- In complex integrated solutions, the building is part of the solution, not around it.
- Do not underestimate the impact of integration and interfaces.
- ROI analysis is part of the iterative process, not an answer.
2.5 Phase 5—Managing the Results

The last thing you want to hear when you are embarking on the design of a new solution is that you will someday need to **redesign** it. However, if you are interested in true maximum long-term rewards, your solution will probably need some ongoing love to keep it current and serving your company well.

There are several typical reasons to consider ongoing modernization of existing material handling systems. You may have an opportunity to reduce your cost of ownership, emerging technology may offer added functionality or safety, or your business may have changed requiring a remodel of your supply chain assets.

### REASONS TO CONSIDER A MODERNIZATION

<table>
<thead>
<tr>
<th>COST</th>
<th>MISSION</th>
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<tbody>
<tr>
<td>Obsolete Components</td>
<td>Business Outgrew Design</td>
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<tr>
<td>High Spare Parts Consumption</td>
<td>Throughput / Demand Increased</td>
</tr>
<tr>
<td>Maintenance Unavailable</td>
<td>Business/Customer Needs Changed</td>
</tr>
<tr>
<td>Unsupported Fragile Software</td>
<td>Location Wrong for Business</td>
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<tr>
<td>Changing Standards</td>
<td>New Control Interface Needed</td>
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<tr>
<td>Equipment Decay</td>
<td>Load Characteristics Changed</td>
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<tr>
<td>Mechanical Instability</td>
<td>New Technologies Emerged</td>
</tr>
<tr>
<td>Changing Workforce</td>
<td>Business Model Changed</td>
</tr>
</tbody>
</table>
What happens over time to most technology investments? Changes in business, normal wear, and father time all erode the original rate of return, causing a decline in the net rewards over time. They are probably still better than what would have been the case in a non-automated scenario, but they are not as good as they could be.

THE EFFECT OF TIME ON TECHNOLOGY ROI

Now, with carefully timed modernizations, the net rewards can be restored or improved upon by applying upgrades, enhancements, or remissioning a system.

THE EFFECT OF MODERNIZATIONS ON ROI
The good news is that the process of ongoing design is much the same as original system design. Diligent Owners will continually audit their technology and its rewards, looking for opportunities for justifiable improvement.

THE MODERNIZATION DESIGN PROCESS

- Regular periodic questioning of return & fit
- What new technologies/practices exist?
- Function, Safety, Cost, Mission changed?
- Focus on experts and the affected.
- Specify results as well as business impact.
- Define ROI and “have to” intangibles.
- Iterative, interactive; Functional Blocks.
- Define the pre- and post-cutover tasks.
- This project affects an existing operation.
- Simulation & sensitivity analysis
- Risk vs. reward management.
- Structured project plan.
Phase 5 Summary

The objective of this redesign phase is to maximize the Owner’s ongoing return on investment and ensure that the solution continues to serve the company in a dynamic world.

The deliverables from this phase are:

- Appropriate reinvestment in technology
- Sustained or improved returns

The key take-aways from Phase 5 are:

- Owning a supply chain solution is a task of ongoing analysis.
- Each Functional Block has a lifecycle and ever changing cost of ownership.
- Modernization projects require at least the diligence of new projects.
3. The Design-Build Business Model

As we mentioned before, the overall 5 Phase project process is referred to as a Design-Build approach; where the integrator and client work in lockstep through a seamless process from inception to completion.

There are however, alternative business models to conduct projects such as hiring a 3rd party consulting firm to perform the design, breaking the project into components and competitively bidding each piece. At HK Systems, the vast majority of our major projects have been conducted under the Design-Build model using this 5 Phase methodology. Our clients and we feel that this approach is the reason that projects succeed.

Here is an overview of the Design-Build business model and its benefits.

3.1 The Guiding Principles

Design-Build is a Client-partner (Integrator) relationship that is based on trust and performance. It lasts as long as both parties perform. Here are the basics:

THE ROLES IN DESIGN-BUILD

- Commits resources to design and Partner education rather than vendor selection
- Commits to continued partnership contingent upon performance
- Relinquishes risk to Partner
- Trades cost of bidding for Owner discount
- Owes Owner assurance of most fair price available
- Accountable to deliver the team’s design

Owner

Partner

TRUST
3.2 The Benefits

Design-Build is a business relationship that requires the Owner to conduct sufficient research to select a fitting, trustworthy partner before the design is complete. The partner (HK) is then responsible for demonstrating superior commitment at a better than market value.

- Most Appropriate Design—The Design Team (HK and Owner) focus on best-fit solution, not selling lowest price bid or finding loopholes in the RFQ.

- No Surprises—The Owner is involved in key design, cost, and vendor decisions.

Continuity—No information handoffs between the Owner, Consultant, Integrator, and Contractors.

TRADITIONAL MODEL

DESIGN-BUILD MODEL
Lower overall cost:
- No profit on contingency
- No purchased unused contingency
- Open-book discounts due to HK’s savings on bid process
- Owner procurement and project management reduced

Shorter schedule yields faster ROI

DESIGN-BUILD VS. TRADITIONAL SCHEDULE COMPARISON

Lower Risk—Since one party is responsible for the final design, performance commitments and turnkey delivery of the final solution, all of the risk shifts to HK as the Design-Build partner, not the Owner or a 3rd party.
So there you have it. A proven process to take your hunch, bright idea, or funded project to the point of optimum final design and ready to build. We at HK Systems stand ready to support you in your small, large, or aftermarket supply chain projects.

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