2.1 Work Flow

Increasing productivity through production-line principles requires standardized work processes, i.e., procedures, facilities, skills, man-hour requirements and durations. In theory, each production line consists of only sequenced activities, e.g., marking, cutting, assembling, etc., needed to fabricate pipe pieces for one family. As this would require needless duplication of facilities, the pipe-piece flows for various families are selectively merged and coordinated. A singular goal is to avoid, or at least minimize, reversals in the direction of basic work flow.

Routings are established so as to maintain families while sometimes joining them based upon similarities of required work processes. Figure 2-1 illustrates commonalities in processes which are the bases for determining how families can share flow lanes.

Work flows may be virtual, i.e., existing facilities do not necessarily have to be rearranged. Regardless of whether flows are real or virtual, flow patterns will differ based upon the area allocated for pipe-piece fabrication, the number and sizes of doors in the pipe-shop building and the arrangement and capacities of available facilities. Other factors that influence flow patterns are:

- the degree, by pipe-piece family, that peak work loads are normally offset by subcontracting, and
- what work processes are normally subcontracted regardless of work load, e.g., plastic-lining steel pipe and small radius bending of large diameter pipe.

PIPE PIECE FAMILY		FABRICATION SEQUENCE					TREATMENT SEQUENCE					FLOW LANE	
CODE	NAME	CT	BN	FT	WL	GR	PK	PT	LN	GL	ETC.	CODE	NAME
01	STRAIGHT	1		2	3	4	5	6				AA	STRAIGHT PIPE
11	BENT AFTER FAB	1	5	2	3	4	6	7					
64	LINED	1		2	3	4	5		6				
68	GALVANIZED	1		2	3	4				5			
41	BENT BEFORE FAB	1	2	3	4	5	6	7				BB	ASSEMBLED PIPE
51	FABRICATED PIECE	1		2	3	4	5	6					
65	LINED	1	2	3	4	5	6		7				
69	GALVANIZED	1	2	3	4	5				6			

LEGEND

CT: Cutting BN: Bending FT: Fitting, assembling, etc. WL: Welding
GR: Grinding
PK: Pickling PT: Painting LN: Lining GL: Galvanizing

Figure 2-1: Pipe-piece families are joined based upon similarities in required operations in order to optimize equipment utilization. This results in organization of flow lanes for shop control. The numbers under each process indicate the sequence of fabrication.

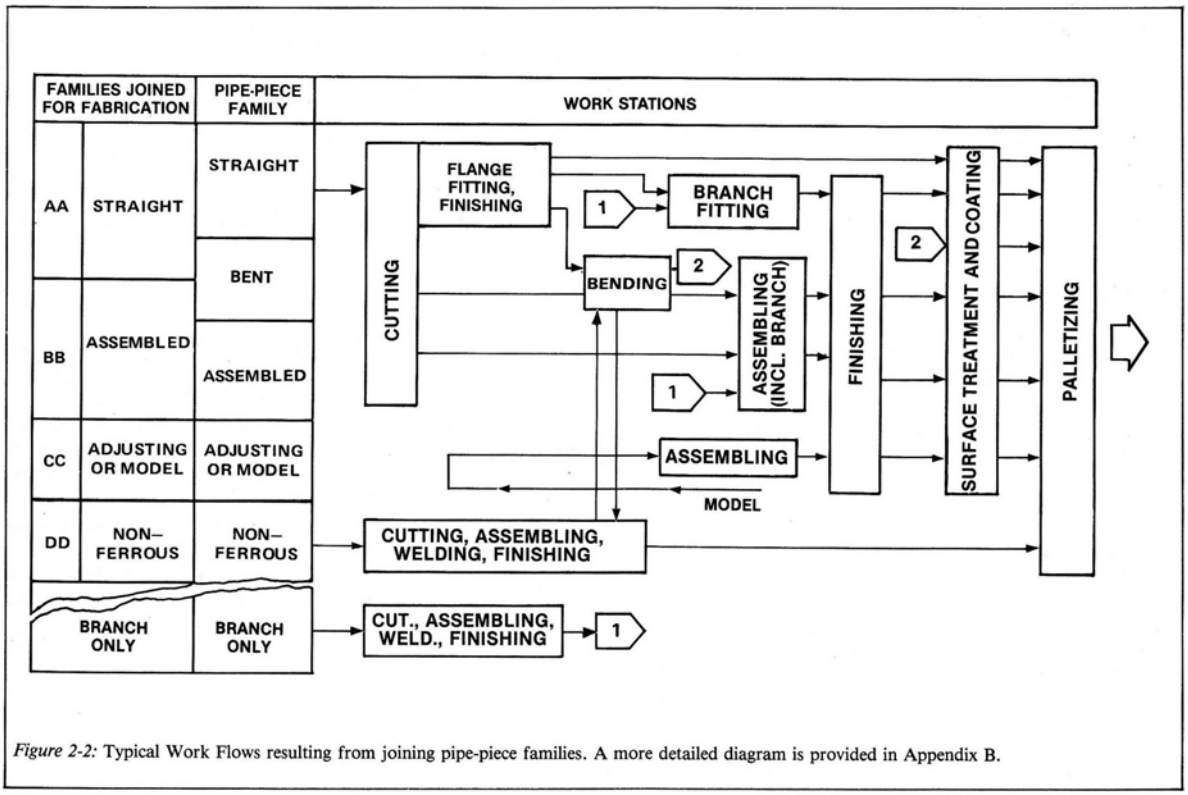

Figure 2-2: Typical Work Flows resulting from joining pipe-piece families. A more detailed diagram is provided in Appendix B.

Figure 2-2 schematically illustrates coordinated work flows for a manually operated, competitive pipe shop which employs PPFM. Figure 2-3 shows the shop arrangement and work flows in more detail. Photographs of the same shop's painting and palletizing areas are shown in Figure 2-4.

2.2 Shop Organization

The routing of PPFM work flows are peculiar to each shipyard's circumstance. However, basic managerial functions as described in Figure 2-5 are the same.

Further, PPFM is an industrial science. Implementation requires managers who understand the principles of Group Technology (GT) and a product-oriented work breakdown for building an entire ship, i.e., integrated hull construction, outfitting and painting. For example, they are required to manage statistical process analyses to improve pipe-shop methods which contribute to improving overall shipyard productivity. Thus, the pipe-shop positions of manager, deputy manager and planning and control manager are valuable training assets for further development of *shipbuilding engineers.*

There are no options. The realities of competition require that shipbuilding engineers/managers be:

- college or equivalently educated,
- rotated in pipe-shop positions, and
- experienced in other shipbuilding functions.

The assignment of responsibilities to first and second level supervisors, i.e., foremen and assistant foremen, depends on both routing of work flows and palletizing requirements. Figure 2-6 shows how such responsibilities are apportioned for the pipe shop described in Figure 2-3. Figure 2-7 is a similar presentation for a smaller pipe shop which also employs PPFM.

PPFM employs production line-principles which include fixed work stations. However, workers are trained and continuously rotated in all jobs because:

- reassigning pipe-shop workers is the best way to adjust for different pipe pieces required in varying quantities,
- their awareness of how work stations impact on each other permit them to contribute to fine tuning flow lanes, and
- universal experiences are necessary to develop prospective foremen and assistant foremen.

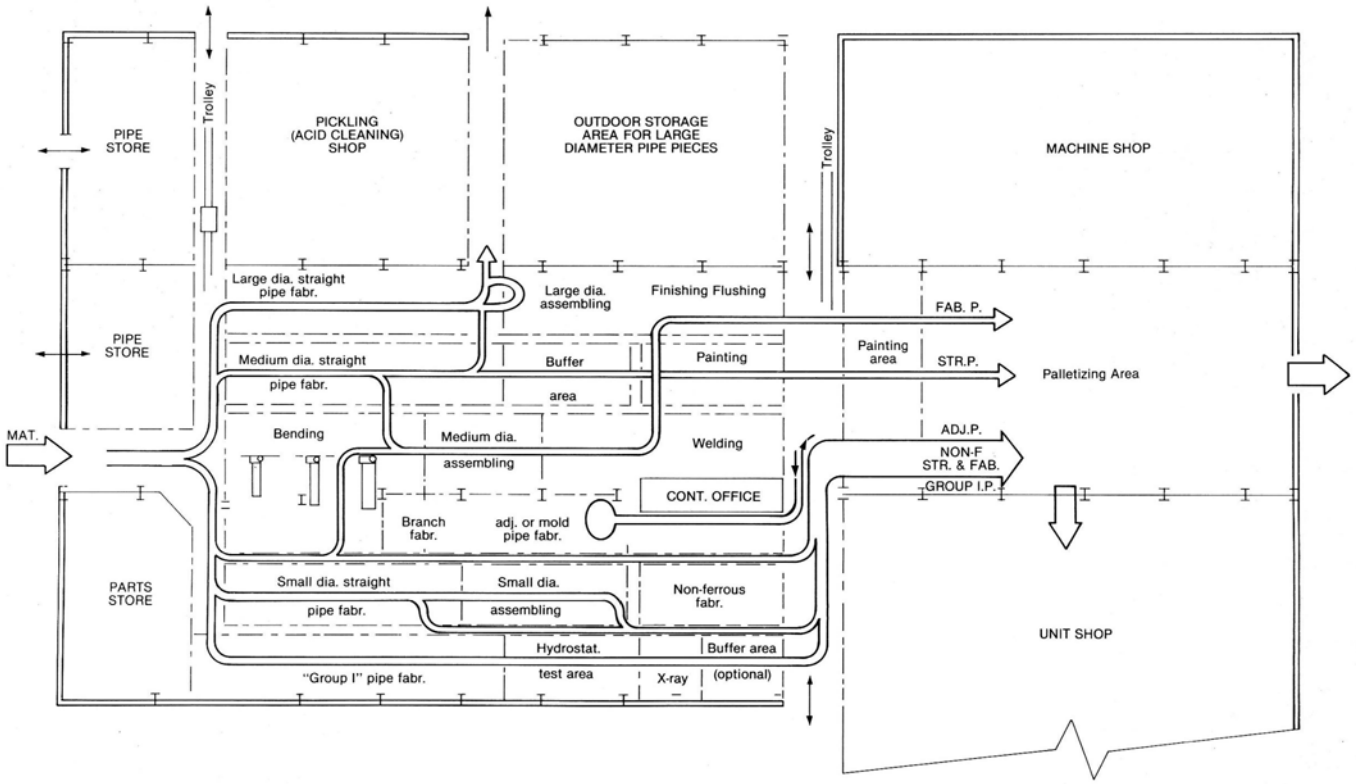

Figure 2-3: Typical work flows for the manually operated pipe shop in IHI Kure Shipyard which employs PPFM. Planned nominal capacity: 450 tons/month. Shop area less palletizing area: 4,167 square meters. Planned efficiency: 0.1 tons/month/square meter. Maximum output: 490 tons/month during construction of large ships. Current output: 260 tons/month for construction of medium sized ships. Productivity varies between 1 and 2 man-hours/pipe piece depending on ship sizes, required surface treatments, etc. Some painting is performed in the outdoor storage area for large diameter pipe pieces.

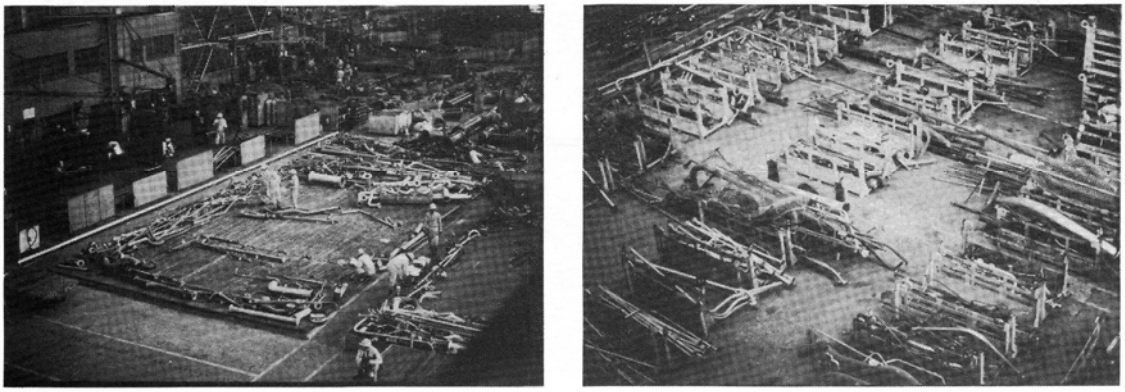

Figure 2-4: Pipe Shop, IHI Kure Shipyard. *Left:* Painting area. The control office appears in the left background. Welding stations are in between. *Right:* the palletizing area is next to the painting area and occupies 2,000 square meters.

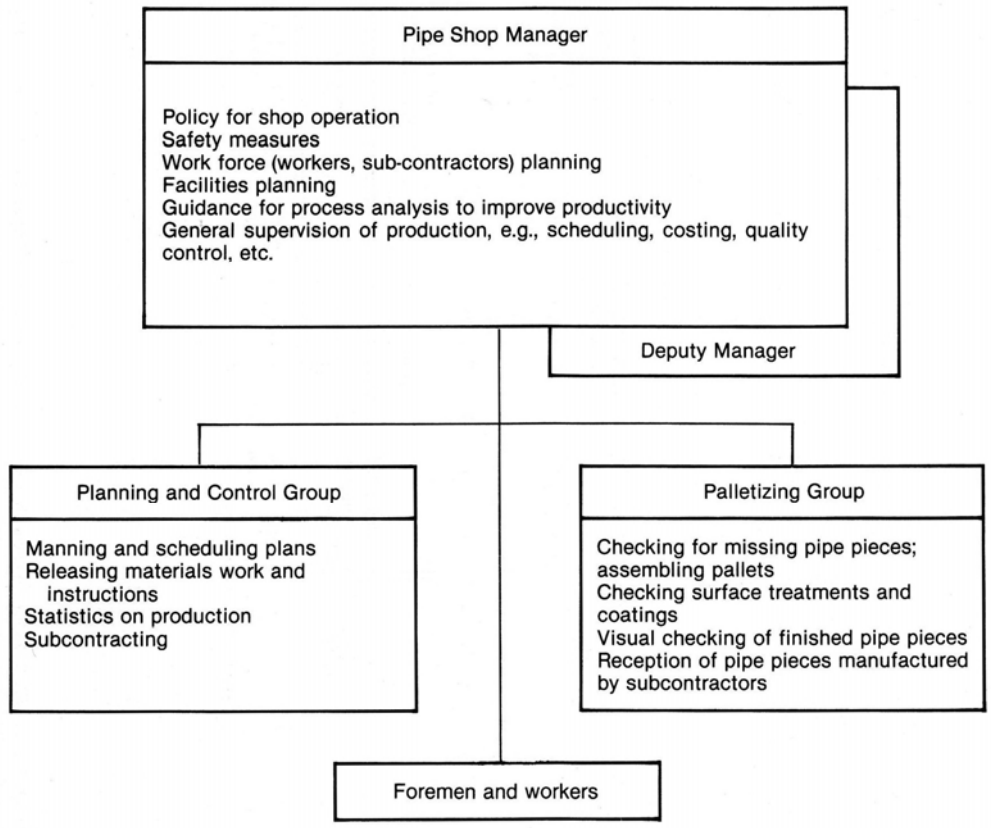

Figure 2-5: Typical Pipe-Shop Control Organization.

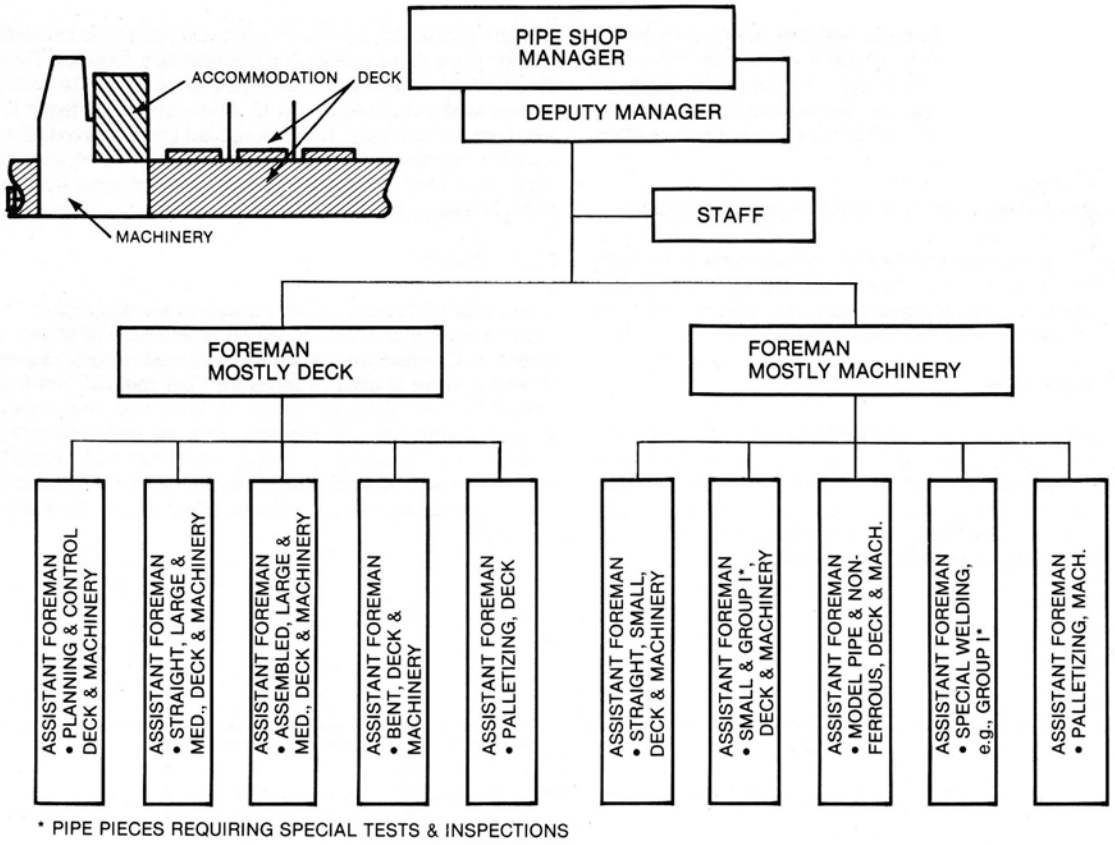

Figure 2-6: Organization of a shop which employs PPFM is dependent on how the various production lines are made to merge in order to establish flow lanes. Effective alternatives exist, but as PPFM is applied Group Technology all must reflect reasonable separation by problem areas. As shown, one way to apportion responsibilities is to separately address the basic outfit zones for which most pipe pieces are required (DECK and MACHINERY). This type organization is applied flexibly so that the shop manager can direct any requirements, e.g., pipe pieces for ACCOMODATION, anywhere in order to balance work flows.

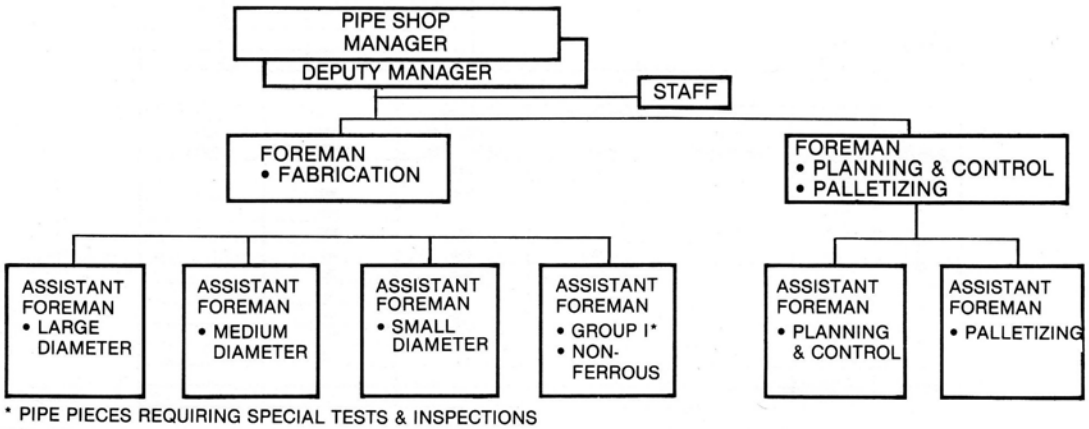

Figure 2-7: Another effective organization reflects separation into problem areas using diameter size as criterion. Similarly, this type organization is applied with a degree of flexibility.

2.3 *Work Load Forecasting*

Workload is governed by requirements imposed by outfit assembly schedules which virtually disregard pipe-shop capacity and backlog. The work thus imposed must be matched to available shop and subcontractor capacities in order to schedule efficient PPFM. Necessarily, there must be consideration of:

- long-term measures, and
- urgent problems which demand immediate solutions.

Changes in manpower and facilities which result from such considerations, should be consistent with the economic necessity to maintain in-house capacity at a relatively modest level and to regularly rely on subcontractors.

2.3.1 *Long Term*

Plans to adjust facilities, manning and subcontracting policies should be based on the total number of required pipe pieces or man-hours estimated for about the next six months. Circumstances sometimes require that the capacities of subcontractors be immediately reserved dependent upon their capacities relative to expected other demands.

2.3.2 *Intermediate*

Intermediate plans are based upon computer-aided analysis of pipe-piece requirements for the next two months. These are prepared separately for each pipe-piece family and work process as shown in Appendix C. Preparations are made for scheduling accordingly. If the work load greatly exceeds shop capacity, intermediate plans are revised in order to subcontract more work. Printouts are then obtained separately for in-house and subcontract work.

2.3.3 *Weekly*

The schedule resulting from intermediate planning is the basis for computer-produced weekly schedules, also shown in Appendix C, which are leveled and balanced to some degree. However, there is need to integrate "last minute" work as caused by loss, damage, owner changes and ship repair. These requirements are superimposed on each computer-produced weekly schedule. Family identifiers and normally expended man-hours per pipe piece per stage permit preparation of a summary of the combined effect on each flow lane; Figure 2-8.

FAB LANE	UNITS	LAST WEEK	REMAINING FROM LAST WEEK	THIS WEEK	NEXT WEEK
A-A	PCS	346	140	180	250
	MHRS	1570	643	352	1132
B-B	PCS	370	321	825	950
	MHRS	888	227	971	1045
TOTAL	PCS	716	461	1005	1200
	MHRS	2458	861	1323	2177
A-A WORKERS	DIR	20		20	20
	SUB	4		4	4
	XFER	5		2	2
B-B WORKERS	DIR	26		26	26
	SUB	4		4	4
	XFER	3		3	2
TOTAL WORKERS	DIR	46		46	46
	SUB	8		8	8
	XFER	8		5	5

SUB-CONTR.s	UNITS	MAX CAPACITY PER MONTH	COMPLETE LAST WEEK	SCHED THROUGH LAST WEEK	SCHED THIS WEEK	SCHED NEXT WEEK
A	PCS		485	444	658	
	MHRS	1700		905	862	
B	PCS		0	278	106	
	MHRS	700		133	105	
C	PCS		0	165	40	
	MHRS	100		106	36	
D	PCS		93	125	0	
	MHRS	900		655	0	
E	PCS		0	242	113	
	MHRS	230		223	123	
TOTAL	PCS					
	MHRS					

Figure 2-8: A fictitious summary of actual and anticipated work as used by a pipe shop manager during each weekly meeting to assimilate "last minute" requirements, apportion next week's work and adjust resources accordingly. (DIR: direct labor permanently assigned to pipe shop, SUB: subcontract, XFER: temporarily transferred workers from outfit-assembly sections; all are numbers of people)

A summary and a proposed plan for a following week's operations are prepared by the shop's planning and production control manager and are the principal topics at each weekly meeting convened by the shop manager. Foremen and assistant foremen comment about the status of their respective areas of cognizance. Adjustments are made and a plan is finalized. Having commensurate authority, the shop manager can direct:

- transfer of workers between flow lanes,
- overtime, and
- assignment of more work to pre-approved subcontractors.

As another option, outfit progress permitting, temporary transfer of assembly workers to the pipe shop could be requested. Obviously, the flexibility with which a manager can respond is dependent upon how well workers are trained to perform at various work stations.

After the week's work is determined, further leveling and balancing is performed and reflected in detail schedules for each work station within a flow lane. Operators further refine such schedules within limits of their portions of a lot and by half day periods in order to optimize sequences at each work station.

Thus, planning and scheduling for PPFM proceeds in levels of increasing detail. At first, planners are concerned with identifying all required resources. Next, capacity planning is accomplished to minimize work fluctuations. A week before start of fabrication, plans for the next lot are completed and specific work is ordered. Finally, day-to-day operational adjustments are made.

2.4 Information Organization

Ideally, a shop manager's weekly meeting to define next week's work is held on a Tuesday. The previous day is for the shop planning and production control manager to make necessary preparations including analyzing progress information for the workweek just completed. Decisions made at a Tuesday meeting are a "go" sign for overnight computer-preparation of work and material orders. These are based on standard data concerning what, how and when work is to be performed. Distributions are made each Wednesday morning in accordance with the information flow shown in Figure 2-9. Thus, three workdays remain for necessary preparations including organizing and delivering materials to subcontractors.

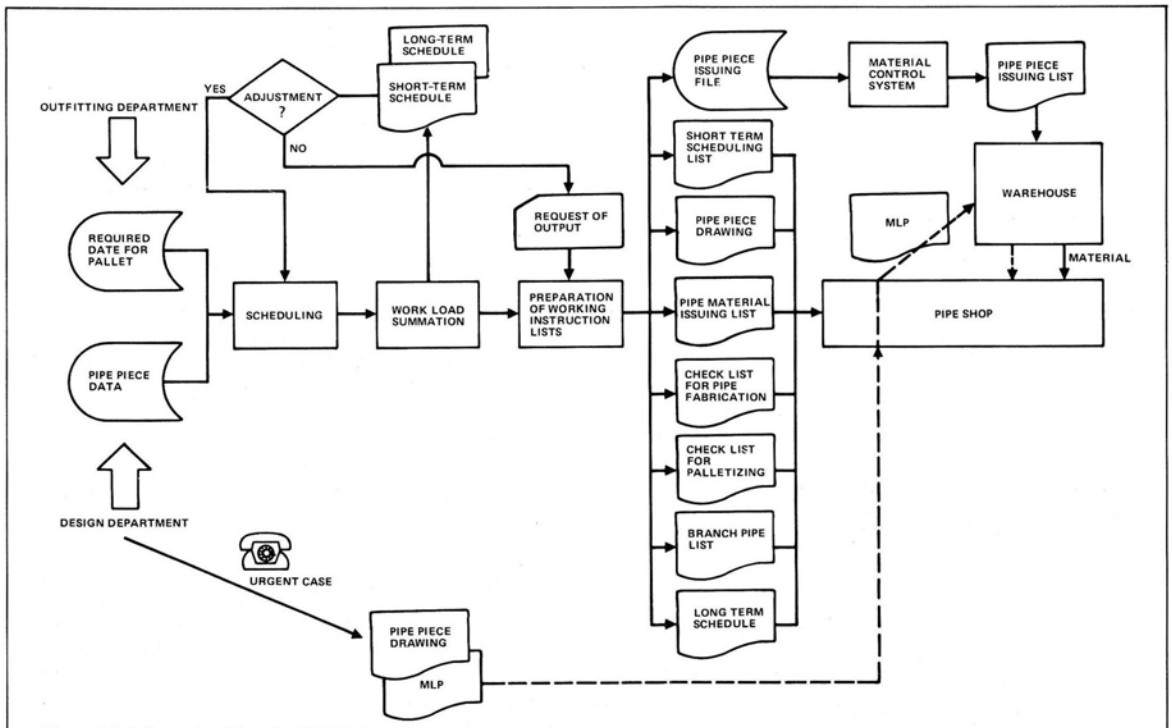

Figure 2-9: Information Flow for PPFM Control.