Report on Scoping
the Apparel Manufacturing Enterprise

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ABSTRACT

This paper identifies a set of manufacturing data interfaces that could be standardized for the effective computer integration of the information required to operate an apparel manufacturing enterprise. The interfaces are called Application Protocols. A method is described to use pieces of information, referred to as Units of Functionality, as building blocks for designing Application Protocols.

KEYWORDS

AMA; APDES; apparel; application protocol; enterprise framework; pattern; PDES; STEP; unit of functionality

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I.   INTRODUCTION

The apparel industry has used computers to great advantage to automate many of its manufacturing processes. However, the manufacturing innovations often stand alone as "islands of automation." Integrating the separate automated processes could greatly improve the effectiveness of the entire enterprise. This paper identifies a set of manufacturing data interfaces that could be standardized for the effective computer integration of the information required to operate an apparel manufacturing enterprise.

Two technology enablers are necessary to foster the development of integration. The first is an enterprise framework that specifies the entire functionality of an enterprise's operation. The second is a set of manufacturing data standards that specifies the interfaces among these functions. This paper specifies a possible set of manufacturing data standards, based on an analysis of a previously proposed enterprise framework.

A straw man for an enterprise framework for apparel manufacturing has been developed under sponsorship of the Defense Logistics Agency (DLA) by the Georgia Institute of Technology [Jay1, Jay2]. This framework is referred to as the Apparel Manufacturing Architecture (AMA). The AMA is a "to be" framework that represents an apparel manufacturing enterprise of the future. It is defined in terms of an activity model that represents the functions required and an information model composed of entities that are used by these functions. The activities and information requirements are represented using the modeling methodologies IDEF0 [USAir1] and IDEF1x [USAir2], respectively.

Once an enterprise framework is recognized as a standard, interfaces among all functions associated with that framework can be identified and standardized as well. These are known as open system standards, because they promote the development of alternative products for

each of the functions. Each product may be unique, but each has the characteristic that it is "plug compatible" into the open system. A straw man for this set of manufacturing data standards can be based on the Standard for the Exchange of Product Model Data (STEP).

STEP is an emerging international standard[1] for representing product data throughout a product's life cycle. In the U.S., an effort has been undertaken to support and accelerate STEP's objectives, and to ensure that the requirements of U.S. industry are incorporated into STEP. This effort is called PDES (Product Data Exchange using STEP). Many of the information requirements as well as the software tools being developed to support STEP are applicable for any manufacturing industry. To serve the needs for a particular industry, Application Protocols (APs) are developed that designate the specific information and application requirements for that industry. The APs draw upon integrated resources[2] to share the same information among different APs.

The National Institute of Standards and Technology (NIST) has been working on a project to develop a suite of APs to support computer integration of the apparel product life cycle. This project is sponsored by DLA, and the work is being carried out in cooperation with the Computer Integrated Manufacturing Committee of the American Apparel Manufacturers Association (AAMA). The project has been named the Apparel Product Data Exchange Standard (APDES) project.

The APDES project is part of a substantial program sponsored by DLA to improve apparel manufacturing technology. The DLA program is advancing technology from traditional size-based methods (ready-to-wear) to methods that use body measurement data directly (made-to-measure). Additionally, the program is advancing production methods from fixed procedures based on standard products to flexible, computer-integrated manufacturing using product representation standards to communicate requirements. The new technologies developed will lead to better fit, higher product quality, economical unit-production methods, and quick response. All told, the program is a broad evolution toward integrated enterprises,

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[1]Refer to ISO 10303-1, *Industrial Automation Systems and Integration—Product Data Representation and Exchange—Overview and Fundamental Principles*, to be published.

[2]Integrated resources are "a set of STEP Parts [separate documents in the STEP (ISO 10303) series] which provide application-independent information models for widely-used types of information. Integrated resources support communication between diverse applications by providing an agreed upon set of definitions and meanings for data that are independent of specific application requirements" [Kramer].

in which all phases of a product's life cycle are coordinated through a framework of standards, concurrent engineering practice, and supporting technology.[3]

The goal for the APDES project is to develop manufacturing data standards based on STEP that will support integration of the projects that DLA is sponsoring. The first objective, when the APDES project began, was to demonstrate the feasibility of using STEP for apparel. The objective was accomplished by developing an information model for pattern data using STEP technology [Lee1]. The information model was represented in the EXPRESS modeling language [ISO11]. The model was implemented in a computer program that exchanges pattern data between two proprietary industry formats [Moncarz]. A neutral set of data structures, based on the information model developed, was used as the intermediary in this process. It was concluded that STEP APs can provide the information interfaces to integrate the apparel product life cycle.

The timeline required for integrating the DLA-sponsored research projects is insufficient to enable the development and integration of formal STEP APs. A formal STEP AP that is developed according to ISO guidelines [Palmer] requires an extensive, consensus gathering effort. Instead, a suite of "prototype" APs will be developed (in the short term) for the APDES project.[4] A prototype AP will not require industry consensus, and it will consist of four main components:

> Scope: general description of the information requirements and the applications supported

> Application Reference Model (ARM): an information model that formally describes the information requirements and constraints for an application domain. The model uses application-specific terminology and rules familiar to an expert from the application domain. The model is independent of any physical implementation. In a prototype AP, the ARM is expressed in the formal computer language, EXPRESS, and is used in implementing the application

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[3]Selected papers from DLA's sponsored apparel research are published in the annual Academic Apparel Research Conference proceedings. The most recent conference was held February 17-18, 1992 [DLA].

[4]NIST is concurrently working on the development of formal STEP APs for the apparel industry [Lee2].

interfaces[5]

Conformance Testing (CT) Requirements: testing requirements to demonstrate that an application that incorporates the prototype AP does so correctly

Usage Guide: a manual that contains a written description of the Scope, the Application Reference Model, and the Conformance Testing Requirements to enable a developer to implement the AP into an application

A formal STEP AP requires one more component:

Application Interpreted Model (AIM): "a model that describes the interpretation of the integrated resource constructs that provide functional equivalence to the AP's information requirements as specified in the application reference model. The form of an AIM is an EXPRESS schema" [Palmer].

The AIM will not be included in the prototype APs developed, in order to expedite the development of the prototype APs. In the long term, the prototype APs will serve as straw man APs to help in the development of formal STEP APs for the apparel industry. The formal STEP APs will be developed in full conformance with STEP standards, including the attainment of industry consensus as required by STEP procedures.

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[5]In a formal STEP AP, the ARM can be described in one of three information modeling languages (EXPRESS, NIAM [Nijssen], or IDEF1x), and is developed from the point of view of the application domain, without regard to the rest of STEP's resources. It is then mapped to the AIM, which is written in EXPRESS, and uses constructs from the STEP integrated resources. An application that implements the AP will be based directly on the EXPRESS version of the AIM.

II.   APs REQUIRED

It is important to identify the set of APs that will be needed for the entire apparel manufacturing enterprise before beginning the actual development of particular APs. Identifying the entire set of APs in advance provides a plan for developing them and allowing for the effective "interoperability" among the AP implementations. In particular, the APs that are determined to have the greatest industry impact can be assigned the highest priorities for development. Furthermore, knowing how a particular AP fits into the "big picture" is helpful for developing that AP.

The set of APs was identified mainly by studying the AMA–in particular the IDEF0 and IDEF1x diagrams. The goal was to determine a set of APs that supported all of the functions identified in the IDEF0 diagrams and provided all of the information entities identified in the IDEF1x diagrams. Additionally, knowledge of industry needs in general and DLA needs in particular were considered in identifying the set of APs. For example, the ready-to-wear pattern making AP has application in currently available pattern making CAD systems. The made-to-measure pattern making AP has application for new systems that are being developed for the future.

In all, fifteen APs were identified:
- Ready-to-wear pattern making
- Made-to-measure pattern making
- Garment style development
- Marker making and cutting
- Sewing and assembly
- Cost estimation
- Quality control
- Manufacturing planning
- Production scheduling
- Packing and shipping
- Material procurement
- Manufacturing resource maintenance
- Production resource allocation
- Sales and marketing
- Inventory maintenance.

It is recognized that the AMA is a straw man, and that changes and enhancements to it are expected before the AMA is accepted by industry. Nevertheless, the current version of the AMA provides a sufficiently comprehensive model for determining a set of APs that can be

used to integrate the apparel manufacturing enterprise. The APDES project team is in close contact with the AMA developer and will address the consequences of AMA modifications to the APDES project as warranted.

The list of APs, showing the activities supported by each and the information requirements provided by each, is shown in Table 1 on pages 6 and 7.

Table 1. Application Protocols for an Apparel Manufacturing Enterprise

Application Protocol	Activities Supported	Information Requirements
Ready-to-wear pattern making	Create or modify the pattern pieces that make up a garment for a particular size, and grade the pattern pieces for other sizes.	Pattern piece specifications for a particular garment type, style, and size; grading rules to modify the basic pattern pieces to fit other specified sizes
Made-to-measure pattern making	Create or modify the pattern pieces that make up a garment for a particular set of body measurements.	Pattern piece specifications for a particular garment type, style, and set of body measurements–more comprehensive than the typical one or two measurements that characterize the size for ready-to-wear apparel
Garment style development	Create or modify a garment's style.	Garment shape, fit, materials, and the general construction features that specify the style concept; customer requirements
Marker making and cutting	Based on production orders, create markers from pattern pieces, and use those markers to create cut parts.	Pattern piece shapes, orientation constraints to fabric; production orders; information required to create markers to be used for cutting fabric; information characterizing the cut parts
Sewing and Assembly	Sew separate pattern pieces together, attach trims and accessories, and do other stitching, such as decorative stitching, as required.	Information used for assembly of cut pattern pieces–includes piece-to-piece relationships, seam allowances, type of stitching for assembly, as well as any other stitching required, such as decorative stitching; specifications for how all the garment sub-assemblies, including trims and accessories, are related
Cost estimation	Estimate the cost for manufacturing a particular number of garments.	Amount and type of fabric; construction details, including materials; manufacturing procedures; material and labor costs; costing information obtained from producing a sample garment

Quality control	Establish quality control standards, inspect materials and finished garments, and take corrective action on rejected materials or finished goods.	Quality standards and inspection data–to provide in-process quality control, as well as quality assurance reports, at critical manufacturing areas–including fabric and other material inspections, completed garment inspections, and other inspections at important intermediate stages of manufacturing

Table 1. Application Protocols for an Apparel Manufacturing Enterprise (continued)

Application Protocol	Activities Supported	Information Requirements
Manufacturing planning	Create process plans for manufacturing particular garments, taking into account the capabilities of the factory.	Process planning information–includes identification of the fabrics, construction materials, and manufacturing procedures used for manufacturing a particular garment; specifications for sequencing manufacturing operations
Production scheduling	Schedule production operations.	Specifications for manufacturing operations and production orders; equipment and employee availability
Packing and shipping	Pack finished goods and distribute them, either to the customer or to inventory.	Information required to pack finished goods and distribute them, either to the customer or to inventory–includes customer requirements, shipping orders, container requirements, stock of containers and finished goods
Material procurement	Determine suitable vendors, and procure materials needed for production.	Material sources, material requirements for a production period, and procurement status
Manufacturing resource maintenance	Maintain the information characterizing the factory's equipment and human resource capabilities.	Characteristics of a plant's manufacturing resources in terms of equipment capacity, employees, and employee skill levels
Production resource allocation	Assign manufacturing location, equipment, and operators for a particular production program.	Information to match employees to equipment according to equipment capabilities, employee skill levels, and plant scheduling; plant capacity
Sales and marketing	Determine customer requirements, and solicit orders.	Customer requirements, style, fabric; customer orders, production and delivery schedules
Inventory maintenance	Maintain inventories of materials and finished goods.	Information required for storing, retrieving, and dispatching materials and finished goods

III.   MAPPING THE APs TO THE AMA

The AMA is defined in terms of a functional framework and an information model composed of entities that are used by these functions. The functions represented in the activity model that are supported by each of the APs have been determined. All of the functions incorporated in the AMA activity model are mapped to the set of APs identified. The mapping of the APs to the functions in the activity model is shown in Appendix A. The reverse mapping (i.e. how the functions in the activity model map back to each of the APs) is shown in Appendix B.

The particular AMA functions grouped with each AP gives the reader an idea of the type of functions each AP supports. A one-to-one correspondence between AMA functions and the actual AP functions is not intended.

The parts (or views) of the information model and the entities that are incorporated by each of the APs have also been determined. The mapping of the information model to the APs is shown in Appendix C. All of the information model views and entities in the AMA are mapped to the set of APs identified. The APs provide complete coverage of the AMA, in terms of the AMA's information model.

The particular AMA entities grouped with each AP gives the reader an idea of the type of entities each AP uses. A one-to-one correspondence between AMA entities and the actual AP entities is not intended.

The reverse mapping (i.e. how the APs map back to each information model view and each entity) is shown in Appendix D. The reverse mapping is useful to help determine what pieces of information span more than one AP. That knowledge will be helpful in determining Units of Functionality, the subject of the next section.

IV.   UNITS OF FUNCTIONALITY AS BUILDING BLOCKS FOR APs

Currently, NIST is developing the ready-to-wear pattern making AP. This AP is based on an updated version of the apparel pattern information model previously developed by NIST. Much of the effort expended for developing this AP will be leveraged in developing succeeding APs, as a consequence of defining "Units of Functionality." A Unit of Functionality (UoF) is composed of a group of entities that can be associated together to form a single concept within the context of an AP. Hence, an AP is composed of a collection of UoFs. A good candidate for a UoF is a unit of information that can be shared among two or more APs. Choosing UoFs in this manner simplifies integration of those APs, and leverages the effort of developing multiple APs.

A discussion of the reasoning used to determine a set of UoFs to use for two of the APs should clarify how UoFs are selected. A set of UoFs that will be used to design the ready-to-wear and the made-to-measure pattern making APs have been determined. These UoFs and their meanings follow:

UoF	Meaning
pattern	collection of pattern pieces that make up a style
size	one or more designations that identify the size of a pattern
grading	information that can be used to modify a pattern of a particular size to other sizes
fit	collection of anthropometric measurements used to determine the dimensions of a pattern

These two APs will be composed of the following UoFs:

AP	UoFs
ready-to-wear pattern making	pattern, grading, size
made-to-measure pattern making	pattern, fit

The particular composition of UoFs for these two APs was carefully chosen. The pattern UoF, which includes all the information that is necessary for its specification and testing, will be used in its entirety in the ready-to-wear and the made-to-measure pattern making APs. It will also be used in other APs where pattern shape information is important.

With proper application software, the grading UoF will provide information to transform the pattern UoF to other sizes. The grading UoF will reference the pattern UoF and the size UoFs to which it applies.

The size UoF was made a separate UoF for several reasons. A ready-to-wear garment is given a size designation based on one or two dimensions of the garment (generally, one longitudinal dimension and one circumferential dimension). Unfortunately, the dimensions used for a particular size designation are arbitrary and vary from manufacturer to manufacturer, as well as from country to country. A size designation without additional information is not complete to unambiguously represent the size of a particular garment. Currently, the European community is working to develop size standards for ready-to-wear apparel that will be more complex, though more reliable, than existing sizing systems [Palaganas]. The information that characterizes a size can be represented separately from the information in the pattern and grading UoFs. If the internal structure of the size UoF needs to be changed, the pattern and grading UoFs will not be affected.

Furthermore, the size UoF (for a ready-to-wear garment) will have similar types of entities as the fit UoF (for a made-to-measure garment). This similarity will simplify communications involving data conversions and/or data sharing between ready-to-wear and made-to-measure applications.

UoFs will continually be defined as the APs development effort proceeds. Defining UoFs carefully will allow multiple APs to share the same UoFs. In this way, the UoFs can be considered building blocks for developing application interfaces.

V. SUMMARY

Fifteen application areas for AP development have been identified within the framework of the AMA.

Currently, NIST is developing the ready-to-wear pattern making AP. This AP is based on an updated version of the information model previously developed by NIST [Lee1]. Much of the effort expended for developing this AP will be leveraged in developing succeeding APs. The leveraging is a consequence of defining units of functionality and using them as building blocks for AP development.

The interface specifications developed in the APDES project are intended to be used in support of the apparel manufacturing research projects that DLA is supporting, to help in integrating those projects within the AMA. For a proposed STEP AP to be approved by the official STEP sanctioning organization–the International Organization for Standardization–an extensive, consensus gathering effort in the industry must be undertaken. The set of APs defined, the UoFs identified, and the APs that are currently being developed in the APDES project can be used as "straw men" for developing official STEP standards for apparel.

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APPENDIX A.   MAPPING THE APs TO THE ACTIVITY MODEL

This appendix details how the set of APs specified by this paper maps to the AMA's activity model, presented in the AMA report [Jay1]. The activity model is a hierarchical model–its functions are represented in multiple levels of decomposition. Many of the functions represented in the model can be decomposed into lower level functions.

The table below consists of three columns. The first column lists the activity model function number that is defined in the AMA report. If a function is decomposed into lower level functions, those functions are indented. The second column is a description of the function, taken verbatim from the AMA report. The third column gives an abbreviation for the AP[6] that supports that activity model function. An AP is specified for an activity model function, only if that function has no further decompositions in the AMA model. If the function can be further decomposed, the third column contains a dash ('–').

Activity Number	Description	AP Abbrev.
A-0	Operate an Apparel Manufacturing Enterprise (Context)	
A0	Operate an Apparel Manufacturing Enterprise	–
A1	Develop and Market Garments	–

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[6]The following abbreviations for the selected APs are used in Appendices A, C, and D:

Full Name of AP	Abbreviation of AP
ready-to-wear pattern making	grading
made-to-measure pattern making	pattern
garment style development	style
marker making and cutting	marker
sewing and assembly	assembly
cost estimation	cost
quality control	quality
manufacturing planning	planning
production scheduling	scheduling
packing and shipping	packing
material procurement	procurement
manufacturing resource maintenance	resources
production resource allocation	allocation
sales and marketing	sales
inventory maintenance	inventory

A11	Market Style Ideas to Customers	–
A111	Create Style Portfolios	style
A112	Contact Potential Customers	sales
A113	Market Style Concepts	sales
A114	Develop Style Concept for Customer	style
A12	Develop Garment Style	–
A121	Control Style Development	style
A122	Develop Construction Detail	–
A1221	Identify Garment Features	style
A1222	Assign Construction Materials	style
A1223	Develop Construction Features	style
A123	Develop Garment's Shape	–
A1231	Develop Garment's Fit	grading, pattern
A1232	Develop Grade Rules	grading
A1233	Develop Garment's Pattern	grading, pattern
A1234	Create New Pattern	grading, pattern
A13	Work Out Sale Details	–
A131	Prepare Quotations for Customer	cost
A132	Determine Sample Requirements	sales
A133	Modify Style Concept	sales
A14	Provide Garment Samples	–
A141	Control Sample Production	–
A1411	Schedule Sample Production	scheduling
A1412	Make Sample Marker	marker
A1413	Release Sample Orders for Production	allocation
A142	Produce Sample Garments	–
A1421	Cut Fabric	marker
A1422	Sew Sample Garments	assembly
A1423	Examine Sample Garment Fitting	quality
A1424	Rework Sample Garments	quality
A143	Test Sample Garments	quality
A15	Prepare Process Plans	planning
A2	Provide Manufacturing Support Services	–
A21	Establish Quality Control Practices	–
A211	Establish Garment Quality Standards	quality
A212	Establish Material Quality Standards	quality
A213	Develop Test and Inspection Procedures	quality
A22	Develop Suppliers for New Materials	–
A221	Complete Material Description	procurement
A222	Invite Bids for New Materials	procurement

A223	Evaluate Bids and Select Vendors	procurement
A23	Maintain Manufacturing Resource Data	–
A231	Develop Process Specifications	resources
A232	Maintain Equipment Capability Data	resources
A233	Maintain Plant Capacity Data	resources
A234	Maintain Operator Skills Data	resources
A3	Plan and Prepare for Manufacture	–
A31	Receive and Confirm Sales Order	–
A311	Initiate and Confirm Sales Program	sales
A312	Select Manufacturing Location	allocation
A313	Post Program on Master Production Schedule	scheduling
A32	Pre-Process Reorders	sales
A33	Complete and Release Program	–
A331	Assign Fabrics	planning
A332	Assign Fabric-Specific Construction Materials	planning
A333	Assign Style for Irregular Production	planning
A334	Create Style Description for Irregular Production	planning
A335	Release Program	planning
A34	Procure Materials	–
A341	Purchase Materials	–
A3411	Determine Program's Material Requirements	procurement
A3412	Collate Material Requirements	procurement
A3413	Select Material Source	procurement
A342	Receive Materials	procurement
A343	Monitor and Control Material Quality	–
A3431	Test and Inspect Material Samples	quality
A3432	Analyze Material Quality	quality
A3433	Release Material for Distribution	quality
A3434	Take Corrective Action on Rejected Materials	quality
A344	Distribute Materials	–
A3441	Assign Storage Locations	inventory
A3442	Store Materials in Warehouse	inventory
A3443	Select Materials for Retrieval	inventory
A3444	Retrieve and Dispatch Materials	inventory
A4	Monitor and Control Production Programs	–
A41	Issue Production Orders	–
A411	Send Production Notification to Customer	sales
A412	Initiate Production Orders	scheduling
A413	Verify Material Availability	procurement
A42	Plan Cutting & Spreading	–

A421	Prepare Marker	marker
A422	Prepare Scaled Sections	marker
A423	Determine Spread Layout	marker
A43	Schedule Production	scheduling
A5	Manufacture Garments	–
A51	Cut Fabric and Collect Garment Parts	–
A511	Schedule Cutting Production	scheduling
A512	Assign Resources and Release Cutting Jobs	allocation
A513	Produce Cut Parts	–
A5131	Spread Fabric	–
A51311	Lay Fabric	marker
A51312	Stop and Process Defects	marker
A51313	Record Actual Spreading Data	marker
A5132	Cut Fabric	marker
A5133	Label Cut Parts	marker
A514	Audit and Ship Cut Package	–
A5141	Inspect Cut Package	quality
A5142	Take Corrective Action	quality
A5143	Ship Cut Package	quality
A52	Distribute Production Schedule to Plants	scheduling
A53	Produce Garments	–
A531	Assign Production Resources	allocation
A532	Sew and Finish Garments	–
A5321	Control Sewing and Finishing Production	scheduling
A5322	Hold Garment Sub-Assemblies	scheduling
A5323	Transport Garment Sub-Assemblies	scheduling
A5324	Process Garment Sub-Assemblies	–
A53241	Set Up Sewing/Finishing Unit	assembly
A53242	Perform Sewing/Finishing Operations	assembly
A53243	Inspect Garment Sub-Assembly	quality
A53244	Re-Work Garment Sub-Assembly	assembly
A533	Grade and Sort Garments	–
A5331	Grade Garment Quality	quality
A5332	Carry Out Minor Repairs	quality
A5333	Pack Garments in Storage Containers	packing
A534	Attach Accessories	assembly
A54	Perform Quality Audit	–
A541	Inspect Finished Garments	quality
A542	Analyze Finished Goods Audit Report	quality
A543	Release Finished Garments	quality

A544	Re-Grade Garments	quality
A6	Distribute Manufactured Garments	–
A61	Receive and Stock Garments	–
A611	Receive Garments in Warehouse	inventory
A612	Assign Storage Locations	inventory
A613	Move Garments to Storage	inventory
A614	Restock Leftovers from Packing	inventory
A62	Dispose Irregular Garments	packing
A63	Receive and Consolidate Shipping Orders	packing
A64	Pack and Ship Garments	–
A641	Schedule and Control Packing Operations	–
A6411	Prepare Packing Schedule	packing
A6412	Assign Resources	packing
A6413	Select Garments for Packing	packing
A6414	Retrieve Garments for Packing	packing
A642	Pack Garments	–
A6421	Load Picking Stations	packing
A6422	Collect Garments and Pack in Cartons	packing
A6423	Seal and Sort Cartons	packing
A643	Release Shipments	packing

APPENDIX B.   MAPPING THE ACTIVITY MODEL TO THE APs

The mapping presented in this appendix is the reverse of that in Appendix A. In this appendix, the activity model functions are mapped to each of the APs.

Application Protocol	Activity Model Functions
Ready-to-wear pattern making	A1231, A1232, A1233, A1234
Made-to-measure pattern making	A1231, A1233, A1234
Garment style development	A111, A114, A121, A1221, A1222, A1223
Marker making and cutting	A1412, A1421, A421, A422, A423, A5132, A5133, A51311, A51312, A51313
Sewing and Assembly	A1422, A534, A53241, A53242, A53244
Cost estimation	A131
Quality control	A1423, A1424, A143, A211, A212, A213, A3431, A3432, A3433, A3434, A5141, A5142, A5143, A53243, A5331, A5332, A541, A542, A543, A544
Manufacturing planning	A15, A331, A332, A333, A334, A335
Production scheduling	A1411, A313, A43, A412, A52, A511, A5321, A5322, A5323
Packing and shipping	A5333, A62, A63, A6411, A6412, A6413, A6414, A6421, A6422, A6423, A643
Material procurement	A221, A222, A223, A342, A3411, A3412, A3413, A413
Manufacturing resource maintenance	A231, A232, A233, A234

Production resource allocation	A1413, A312, A512, A531
Sales and marketing	A112, A113, A132, A133, A32, A311, A411
Inventory maintenance	A3441, A3442, A3443, A3444, A611, A612, A613, A614

APPENDIX C. **MAPPING THE INFORMATION MODEL TO THE APs**

This appendix details how the AMA's information model maps to the set of APs specified by this paper. The information model is presented in the AMA report [Jay2] in separate pieces, or views. Each view is assigned a title that is descriptive of that particular view and is contained on one or two pages. Each page is identified by a number that is prefixed by the label "RMX." (The "page" numbers are not in consecutive order.) The page numbers are used to identify the views in the tables presented in this appendix. In addition, the entities of this information model are each assigned a number in the AMA, and these numbers are used to identify those entities in this appendix. The mapping indicates what information model views and what entities are incorporated by each of the APs.

Each table below shows the mapping for one of the APs. Each table is composed of three parts. The first part is the name of the AP; next are the numbers and corresponding titles for the information model views that have been matched with this AP; last are the entity numbers and the names of the entities that have been matched with this AP. The APs and their mapping follows:

Ready-to-wear pattern making

Page Number	View Title
RMX4	Fit and Grading Tables
RMX5	Pattern Description
RMX10	Pattern Grading

Entity Number	Entity Name
7	size
11	grade_table
12	grade_rule
14	pattern
15	pattern_part
16	grad_pat_part
110	pat_grade_point
111	grade_point

Made-to-measure pattern making

Page Number	View Title
RMX4	Fit and Grading Tables
RMX5	Pattern Description

Entity Number	Entity Name
2	fit
7	size
10	measurement
14	pattern
15	pattern_part

Garment style development

Page Number	View Title
RMX1	Product Development and Description
RMX2	Sample Garment Description
RMX5	Pattern Description
RMX6, RMX7	Construction Detail
RMX13, RMX42	Material Description
RMX31	Assignment of Fabric-Dependent Construction Materials

Entity Number	Entity Name
1	style
2	fit
3	constr_detail
6	fabric
7	size
9	sample_req_item
13	base_pattern
14	pattern
15	pattern_part
17	constr_det_item
18	constr_feature
19	constr_ft_item
20	constr_opr
21	constr_ft_mat
22	material
23	process_plan
34	material_variant
37	trim
38	tk_tag_label
39	closure
40	thread
41	accessory
46	prog_item
79	prog_material
81	color
109	style_concept

Marker making and cutting

Page Number	View Title
RMX16, RMX17	Cut Order Planning
RMX18	Marker Making

Entity Number	Entity Name
7	size
16	grad_pat_part
46	prog_item
48	production_order
49	size_scale
50	prod_order_item
51	marker
52	scaled_section
53	marker_section
54	scaled_sec_part
72	scaled_group
98	spread_section

Sewing and assembly

Page Number	View Title
RMX6, RMX7	Construction Detail
RMX26, RMX27	Cut Package Preparation

Entity Number	Entity Name
3	constr_detail
17	constr_det_item
18	constr_feature
19	constr_ft_item
20	constr_opr
21	constr_ft_mat
22	material
28	garment_type
34	material_variant
48	production_order
72	scaled_group

74	prod_ord_mat
78	garment_unit
100	gar_subassembly

Cost estimation

Page Number	View Title
RMX2	Sample Garment Description
RMX3	Sample Production Scheduling
RMX5	Pattern Description
RMX6, RMX7	Construction Detail
RMX13, RMX42	Material Description

Entity Number	Entity Name
3	constr_detail
4	customer
5	sam_prod_assgnmt
6	fabric
7	size
8	sample_req
9	sample_req_item
14	pattern
15	pattern_part
17	constr_det_item
18	constr_feature
19	constr_ft_item
20	constr_opr
21	constr_ft_mat
22	material
34	material_variant
37	trim
38	tk_tag_label
39	closure
40	thread
41	accessory
81	color
94	sal_employee
109	style_concept

Quality control

Manufacturing planning

20	constr_opr
21	constr_ft_mat
22	material
23	process_plan
24	process_step
25	master_schedule
26	process_state
27	proc_input_stat
28	garment_type
29	equip_group
30	buffer
42	plant
43	plant_capacity
44	master_sch_item
45	sales_program
46	prog_item
62	workstation
63	workst_capability
66	job
71	transporter
106	pack_operation
107	operation
108	cr_operation

Production scheduling

Entity Number	Entity Name
1	style
5	sam_prod_assgnmt
6	fabric

8	sample_req
20	constr_opr
23	process_plan
24	process_step
26	process_state
27	proc_input_stat
44	master_sch_item
45	sales_program
47	prog_del_schedule
48	production_order
62	workstation
64	operator
67	cut_rm_schedule
68	cut_rm_sch_item
69	cr_assignment
70	cr_oper_assgnmt
75	plant_schedule
76	plant_sch_item
91	sam_dept_sch
92	sam_dep_sch_item
95	irreg_style
108	cr_operation

Packing and shipping

Page Number	**View Title**
RMX20	Finished Goods Warehousing
RMX21	Shipping Order Description
RMX38, RMX39	Packing and Shipping

Entity Number	**Entity Name**
4	customer
28	garment_type
55	manifest
57	fg_carton
58	shipping order
59	shipping_loc
60	ship_order_item

64	operator
94	sal_employee
95	irreg_style
96	irreg_fg_carton
97	reg_fg_carton
101	cons_ship_order
102	pack_schedule
103	pack_sch_item
104	pack_assignment
105	pack_op_assgnmt
106	pack_operation

Material procurement

Page Number	**View Title**
RMX11, RMX12	Material Procurement
RMX13, RMX42	Material Description

Entity Number	**Entity Name**
6	fabric
22	material
31	material_vendor
32	mat_purchase_order
33	mat_po_item
34	mat_variant
35	stored_item
36	material_location
37	trim
38	tk_tag_label
39	closure
40	thread
41	accessory
48	production_order
81	color
93	material_source

Manufacturing resource maintenance

Page Number	View Title
RMX15	Production Planning
RMX22	Manufacturing Resources - Equipment
RMX23	Manufacturing Resources - Human
RMX40	Manufacturing Equipment Capability

Entity Number	Entity Name
20	constr_opr
29	equip_group
30	buffer
42	plant
43	plant_capacity
61	department
62	workstation
63	workst_capability
64	operator
65	operator_skill
66	job
71	transporter
94	sal_employee
106	pack_operation
107	operation
108	cr_operation

Production resource allocation

Page Number	View Title
RMX29, RMX30	Manufacturing Resource Assignment

Entity Number	Entity Name
24	process_step
29	equip_group
64	operator
73	assigned_oper
76	plant_sch_item
77	assigned_equip

| 80 | work_assignment |
| 94 | sal_employee |

Sales and marketing

Page Number	View Title
RMX2	Sample Garment Description
RMX14	Sales Program Description
RMX15	Production Planning
RMX36	Customer Interaction

Entity Number	Entity Name
1	style
4	customer
6	fabric
7	size
8	sample_req
9	sam_req_item
44	master_sch_item
45	sales_program
46	prog_item
47	prog_del_schedule
95	irreg_style
99	customer_inq
109	style_concept

Inventory Maintenance

Page Number	View Title
RMX19, RMX20	Finished Goods Warehousing

Entity Number	Entity Name
28	garment_type
48	production_order
55	manifest
56	fg_storage_loc
57	fg_carton
78	garment_unit
95	irreg_style
96	irreg_fg_carton

97   reg_fg_carton

APPENDIX D. MAPPING THE APs TO THE INFORMATION MODEL

The mapping presented in this appendix is the reverse of that in Appendix C. The APs are mapped to the information model views in Appendix D.1. The APs are mapped to the entities in Appendix D.2.

D.1. Mapping the APs to the Information Model Views

Each view of the information model is listed by its RMX number (or two) in the left column, and the list of associated APs in the right.

AMA Information

Model View	Associated APs
RMX1	style
RMX2	style, cost, sales, quality
RMX3	scheduling
RMX4	grading, pattern
RMX5	grading, pattern, style, cost
RMX6, RMX7	style, assembly, planning, cost
RMX8	planning, scheduling
RMX9	planning
RMX10	grading
RMX11, RMX12	procurement
RMX13, RMX42	style, cost, procurement
RMX14	scheduling, sales
RMX15	planning, scheduling, resources, sales
RMX16, RMX17	marker
RMX18	marker
RMX19, RMX20	inventory, packing
RMX21	packing
RMX22	planning, resources
RMX23	planning, resources
RMX24, RMX25	scheduling
RMX26, RMX27	assembly
RMX28	scheduling
RMX29, RMX30	allocation
RMX31	style
RMX33, RMX34	quality
RMX36	sales
RMX38, RMX39	packing

RMX40   planning, resources

D.2.   **Mapping the APs to the Entities**

Each entity is listed by its name in the left column, its ID number in the second column, and
the list of associated APs in the right column.

AMA Entity Name	ID	AP Name
accessory	41	style, cost, procurement
assigned_equip	77	allocation
assigned_oper	73	allocation
base_pattern	13	style
buffer	30	planning, resources
closure	39	style, cost, procurement
color	81	style, cost, procurement
cons_ship_order	101	packing
constr_det_item	17	style, assembly, planning, cost
constr_detail	3	style, assembly, planning, cost
constr_feature	18	style, assembly, planning, cost
constr_ft_item	19	style, assembly, planning, cost
constr_ft_mat	21	style, assembly, planning, cost
constr_opr	20	style, assembly, planning, cost, scheduling, resources
customer	4	cost, packing, sales, quality
customer_inq	99	sales
cut_rm_sch_item	68	scheduling
cut_rm_schedule	67	scheduling
cr_assignment	69	scheduling
cr_oper_assgnmt	70	scheduling
cr_operation	108	planning, scheduling, resources
department	61	resources
equip_group	29	planning, resources, allocation
fab_insp_report	85	quality
fab_test_report	86	quality
fabric	6	style, cost, scheduling, sales, procurement
fg_audit_report	89	quality
fg_carton	57	packing, inventory
fg_storage_loc	56	inventory
fg_test_report	90	quality
fit	2	pattern, style

gar_subassembly	100	assembly
garment_type	28	planning, packing, inventory, assembly
garment_unit	78	inventory, assembly
grad_pat_part	16	grading, marker
grade_point	111	grading
grade_rule	12	grading
grade_table	11	grading
irreg_fg_carton	96	packing, inventory
irreg_style	95	scheduling, packing, sales, inventory
job	66	planning, resources
manifest	55	packing, inventory
marker	51	marker
marker_section	53	marker
master_sch_item	44	planning, scheduling, sales
master_schedule	25	planning
mat_insp_report	87	quality
mat_po_item	33	procurement
mat_purchase_order	32	procurement
mat_test_report	88	quality
material	22	style, assembly, planning, cost, procurement
material_location	36	procurement
material_source	93	procurement
material_variant	34	style, assembly, cost, procurement
material_vendor	31	procurement
measurement	10	pattern
operation	107	planning, resources
operator	64	scheduling, packing, resources, allocation
operator_skill	65	resources
pack_assignment	104	packing
pack_op_assgnmt	105	packing
pack_operation	106	packing, planning, resources
pack_sch_item	103	packing
pack_schedule	102	packing
pat_grade_point	110	grading
pattern	14	grading, pattern, style, cost
pattern_part	15	grading, pattern, style, cost
plant	42	planning, resources
plant_capacity	43	planning, resources
plant_sch_item	76	scheduling, allocation
plant_schedule	75	scheduling

proc_input_stat	27	planning, scheduling
process_plan	23	style, planning, scheduling
process_state	26	planning, scheduling
process_step	24	planning, scheduling, allocation
prod_order_item	50	marker
prod_ord_mat	74	assembly
production_order	48	marker, assembly, scheduling, procurement, inventory
prog_del_schedule	47	scheduling, sales
prog_item	46	style, marker, planning, sales
program_material	79	style
quality_report	83	quality
quality_rep_item	84	quality
qc_procedure	82	quality
reg_fg_carton	97	packing, inventory
sal_employee	94	cost, packing, resources, allocation
sales_program	45	planning, scheduling, sales
sam_dept_sch	91	scheduling
sam_dept_sch_item	92	scheduling
sam_prod_assgnmt	5	scheduling, cost
sam_req_item	9	style, cost. sales
sample_req	8	cost, scheduling, sales, quality
scaled_group	72	marker, assembly
scaled_sec_part	54	marker
scaled_section	52	marker
ship_order_item	60	packing
shipping_loc	59	packing
shipping_order	58	packing
size	7	grading, pattern, style, marker, cost, planning, sales
size_scale	49	marker
spread_section	98	marker
stored_item	35	procurement
style	1	style, scheduling, sales
style_concept	109	style, cost, sales
thread	40	style, cost, procurement
tk_tag_label	38	style, cost, procurement
transporter	71	planning, resources
trim	37	style, cost, procurement
work_assignment	80	allocation
workst_capability	63	planning, resources
workstation	62	planning, scheduling, resources