Proposal of a Design Method for Local-Oriented Manufacturing in Developing Countries First Report: Problem Description and Knowledge Representation

Tomoyuki Tamura, Hideki Kobayashi, and Yasushi Umeda

Abstract One of the largest bottlenecks of social sustainability is disparity between developed and developing countries. For decreasing the disparity by raising the quality of life in developing countries, various products and services are expected to be diffused. Conventional products designed for developed countries are not fit to developing countries because of the differences between "locality" including culture, economy, and other situations. We should focus on locality of developing countries in the product design. In this study, we propose "Local-Oriented Manufacturing (LOMan)." LOMan is a concept to encourage designers to focus on locality at manufacturing and use stages. The objective of this research is to propose a design methodology for LOMan. Especially, this paper clarifies the problem of LOMan by describing the results of case studies and a field survey. Based on these results, this paper then proposes "Local-Oriented Manufacturing map (LOMmap)" as a method of knowledge representation for the LOMan design. As a result, we found two kinds of information are needed for supporting LOMan design. One is the information on the local circumstances. The other is the information on influences on a product life cycle caused by the local circumstances. LOMmap supports a designer in determining product specification for LOMan design by representing the two kinds of information.

Keywords Design • Sustainable manufacturing • Social sustainability • Appropriate technology • Local-oriented manufacturing

T. Tamura (✉) • Y. Umeda
Department of Precision Engineering, The University of Tokyo, Tokyo, Japan
e-mail: tamura@susdesgin.t.u-tokyo.ac.jp

H. Kobayashi
Department of Mechanical Engineering, Osaka University, Osaka, Japan

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1 Introduction

One of the largest bottlenecks of social sustainability is the disparity between developed and developing countries. The main disparity is economic disparity, which causes other disparities. A measure to decrease the disparity is to raise the quality of life (QOL) in developing countries by, e.g., diffusing various products and services. However, economy, law, culture, and other situations in developing countries disturb diffusing the products made for developed countries. The situations have different characteristics area by area. "Locality" means such characteristics inherent to the areas where the product is manufactured and used. The current product design for BOP business focuses only on decreasing price of product [1]. Conventional products designed for developed countries cannot be diffused in developing countries because of the differences between the locality in developed countries and that in developing countries. Therefore, we should focus on the locality of developing countries in designing and manufacturing products.

For applying technology to developing countries, the concept of "appropriate technology" was proposed [2, 3]. Advanced technologies in developed countries do not always bring the best results in developing countries because there are some problems caused from the constraints of the economic situations, culture, environment, and other characteristics of developing countries [4]. Therefore, technology should fit to the characteristics of developing countries.

For developing products fit to the developing countries, we need design methodologies in addition to the appropriate technology [5]. Sianipar et al. proposed a design methodology for AT that supports describing and evaluating design results. However, the methodology does not clarify connection between locality and product. Clarifying the connection will be a support to develop the products suitable to locality.

Such design methodologies do not exist.

In this study, we propose "Local-Oriented Manufacturing (LOMan)" as an approach for achieving social sustainability. We focus on the design stage. The design stage is important for LOMan because design decides all characteristics of a product. The LOMan design denotes the design of product that fits to the locality. The objective of this research is to propose the methodology for the LOMan design. In this paper, we propose a method of knowledge representation to determine the specification of the product based on LOMan. The companies may have already collected data and executed market research for local situations. But they did not succeed in LOMan at least in Japanese electric manufacturers. We observed that they failed to structuralize the collected data and to transfer the extracted knowledge to the designer correctly. We, therefore, propose the method of knowledge representation to represent them to the designer in this paper. The rest of this paper is organized as follows: Sect. 2 proposes the idea of LOMan. Then, we clarify the problem of LOMan by describing the results of case studies and a field survey in Sect. 3 and Sect. 4, respectively. Based on these results, Sects. 5, 6, and 7 propose a method of knowledge representation for supporting the LOMan design. Then, Sect. 8 describes an example of the use of the design support tool. After describing the results in Sect. 9, Sect. 10 concludes this paper.

2 Local-Oriented Manufacturing

Currently, each process of product life cycle is executed in different areas, for example, the area where the product is designed and manufactured is different from the area where the product is used, whereas each area has its own locality in, for example, lifestyle, culture, economy, institution, and legislation. Such locality influences on the product design and each process of the product life cycle.

Figure 1 shows an image of LOMan. Locality influences on the product life cycle including manufacturing, remanufacturing, and use stage. At the same time, the products influence on the locality. In LOMan, the product should be fit to the influences. Generally speaking, the product designed and manufactured for one area is not suitable for other areas because of the difference in the locality. Methods for supporting the LOMan design and manufacturing are needed.

LOMan is the concept for designing and manufacturing a product so as to be suitable for locality. LOMan focuses on the locality of the areas for manufacturing, product use, and other life-cycle processes at design and manufacturing stages. For designing a product and manufacturing it based on LOMan, some methodologies are needed, for example, design for LOMan, supply chain management for LOMan, and manufacturing planning for LOMan. We focus on the design stage in this paper; we aim at proposing a design methodology based on LOMan to support a designer in designing a product to be suitable for the locality.

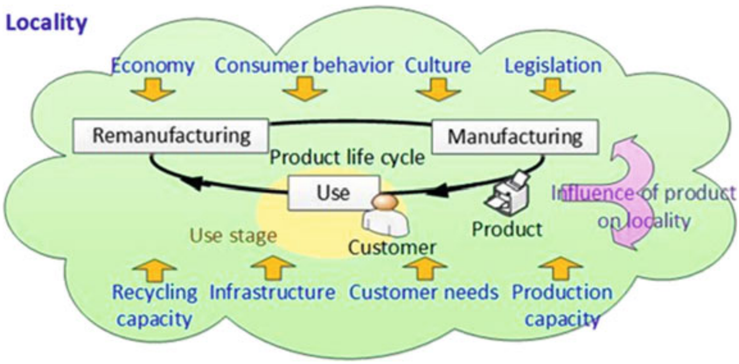

Fig. 1 Image of LOMan

3 Case Studies

By comparing the products for developing countries with those for developed countries, we investigated the influences of the locality where the product is used.

We chose refrigerators and vacuum cleaners for the comparison because they are typical consumer electrical appliances, and therefore, they may reflect the area where the product is used.

3.1 Influences of the Economic Conditions on Refrigerators

We investigated the influence of economic conditions on characteristics of the product. We used GDP per capita as an economic condition (x-axis of Fig. 2) and the average total capacity of the refrigerators as a characteristic (y-axis of Fig. 2). Figure 2 shows the correspondence between the GDP per capita and the average total capacity of refrigerators. Since the correlation coefficient between GDP per capita and the average total capacity of refrigerators is 0.707, there is a correlation between them, whereas the average total capacity of refrigerators in Malaysia and these facts imply that some hidden factors such as culture and lifestyle besides economic conditions influence on the average total capacity of the refrigerators. For the LOMan design, the product should be adopted to these factors.

3.2 Refrigerator

We compared a refrigerator for Indonesia with that for Japan. We chose a refrigerator for Japan that has almost same total capacity as that for Indonesia. The

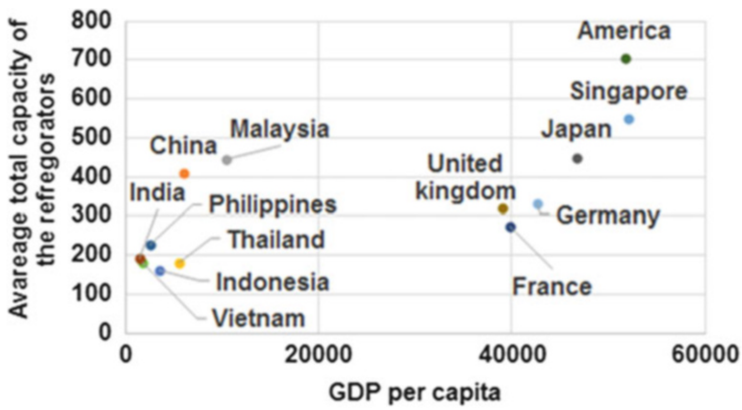

Fig. 2 Diagram of GDP per capita (US$) [6] and the average total capacity of refrigerators (L) [7]

Table 1 Specifications of refrigerators for Indonesia and for Japan

	For Indonesia	For Japan
Price ($)	142	380
Type	GR-Y188	NR-B175W
Manufacturer	Toshiba	Panasonic
Number of doors	1	2
Total capacity (L)	160	168
Color	Purple	Brown
W*D*H (mm)	607*526*1100	480*586*1293
Energy consumption (W)	75 (Compressor)	57 (Compressor)
		120 (Defroster)
Refrigeration room capacity (L)	133	124
Freezer capacity (L)	27	44
Refrigerant	R134a	Isobutane

refrigerator for Indonesia is for a family and the refrigerator for Japan is for a single. Table 1 indicates their specifications. Figure 2 indicates that the total capacity of this refrigerator for Japan is smaller than the average total capacity of the refrigerators in Japan, whereas the total capacity of the refrigerator for Indonesia in this case study has almost same total capacity as the average total capacity of the refrigerators in Indonesia.

First, we compared their specifications (see Table 1). There are three main differences in Table 1. The first difference is in their prices. Price of the refrigerators for Japan is higher than that for Indonesia. It is assumed that this difference mainly comes from the difference of the door numbers. The second difference is in refrigerants. Isobutane has lower global warming potential than R134a, but it is flammable. It is assumed that this difference came from the difference of environmental legislation between these countries. The third difference is in energy consumption. When the compressors are only used, the energy consumption of the refrigerator for Japan is smaller than that for Indonesia. If the defroster is used in the refrigerator for Japan, its energy consumption is higher than that for Indonesia.

Then, we compared their characteristics not expressed in the specifications. The comparison revealed two typical differences. The first difference is in material indication. The plastic cabinets used for the refrigerator for Japan indicate their materials, for example, PS, whereas the refrigerator for Indonesia does not indicate materials. The difference in the environmental legislation in Japan and Indonesia might cause the difference of the material indication. The second difference is their top boards. The top board of the refrigerator for Japan is heat resistant, but the top board for Indonesia is not. In Japan, a microwave oven is often put on a small refrigerator. The difference in usage environment may cause this difference.

From this case study, we confirmed the influence of the locality on the refrigerator. Legislation, usage environment, and economy are example of the elements of the locality. Information on them is needed for the LOMan design.

3.3 Vacuum Cleaner

We compared vacuum cleaners for Malaysia with one for Japan. Table 2 shows specifications of the vacuum cleaners. The comparison of the vacuum cleaners shows, for example, the difference in the power controller on the horse (see Fig. 3). The vacuum cleaner for Japan is controlled by switches. Those for Malaysia are controlled by the hole and the slider. The air goes in through the hole. The amount of the airflow is controlled by changing the size of the hole by moving the slider. The switches of the vacuum cleaner for Japan have four functions, namely, switching the brush on/off in the head, saving energy, changing the power, and switching on/off. The power control by the switch needs smaller area than the power control with the slider, and the switches can have some functions in addition to the power control, whereas having many functions may increase the cost and some of them may not be used by the user. User can adjust the power with the size of the hole.

For the LOMan design, information on the preference of the consumer in the area is needed.

Table 2 Specifications of vacuum cleaners for Malaysia and for Japan

	For Japan	For Malaysia	For Malaysia
Price ($)	334	107	130
Type	EC-PX600	CVC-PH2000CH	VCDC20AV
Manufacturer	SHARP	Cornell	Samsung
Power	850 W (max)	1800 W	2000 W
Weight (kg)	4.3	7.26	5.6

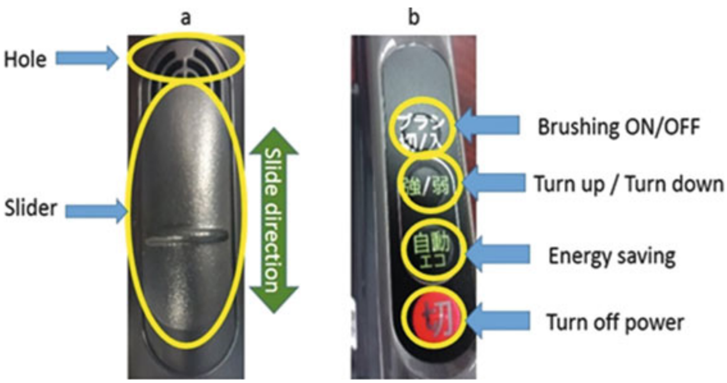

Fig. 3 (**a**) The controller of the vacuum cleaner for Malaysia; (**b**) the controller of the vacuum cleaner for Japan

4 Field Survey

We visited electric shops in Malaysia and looked for the locality of Malaysia in vacuum cleaners and refrigerators.

In Malaysia, two doors, 300–400 L refrigerators with 84–112 US $ are the most selling. In addition, freezers with 200 l capacity for the family are also selling well. The food culture may influence on the choice of the refrigerators, for example, they stored large amount of foods in a freezer.

Samsung advertised their inverters in their refrigerators as "Digital Inverter" in Malaysia. Japanese refrigerator manufacturers did not advertise in such a way. By such advertisement, people who do not know the inverter in refrigerator well may get an impression that inverters used in Samsung refrigerators are special. The impression raises the brand image of Samsung in Malaysia.

5 Framework of the LOMan Design

From the case studies and the field survey, we found the relationship between the locality and a product and its life cycle (see Fig. 4). The locality influences on the product at each process of product life cycle. On one hand, if the influences are good for the user, we should enhance the influences; on the other hand, if the influences are bad, we should decrease the influences. In the LOMan design, a designer should find out the influences of the locality on the product and, if needed, add countermeasures for the influences at design stage. Such countermeasures should be embedded into product design and product life cycle.

For supporting the LOMan design, the following three kinds of information are needed:

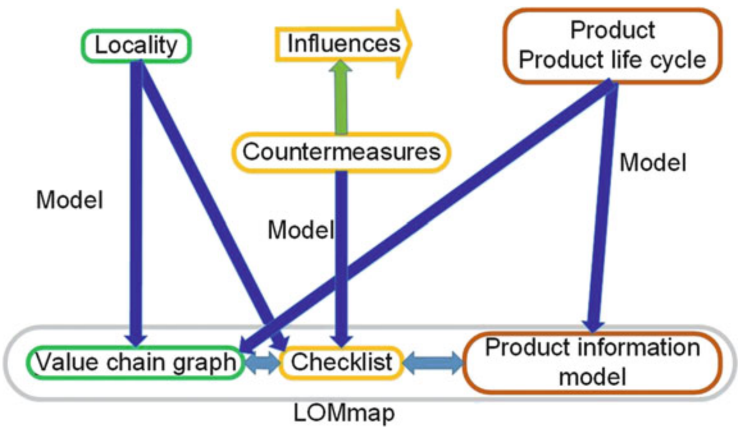

Fig. 4 Requirements for the LOMan design

1. Information on the product life cycle and the areas where the processes of the life cycle are executed, for example, products are sold in Malaysia.
2. Information on the potential influences of the locality on a product life cycle and potential candidates of countermeasures for them; the influences of the floor on the head mechanism of the vacuum cleaner material are an example. To use hard rubber and collect dust is an example of countermeasure.
3. Information on the product, for example, the structure of the vacuum cleaner.

6 Proposal of Local-Oriented Manufacturing Map

6.1 Structure of LOMmap

We propose "Local-Oriented Manufacturing map" (LOMmap) as a knowledge representation scheme for the LOMan design. LOMmap supports a designer in determining the specification of a product for the LOMan design by representing the three kinds of information described in Sect. 5. Figure 5 represents the construction of LOMmap, which consists of a value chain graph, checklists, and a product information model and support tools.

The value chain graph represents the product life cycle and the area where each process of the product life cycle is executed. The checklist represents the potential

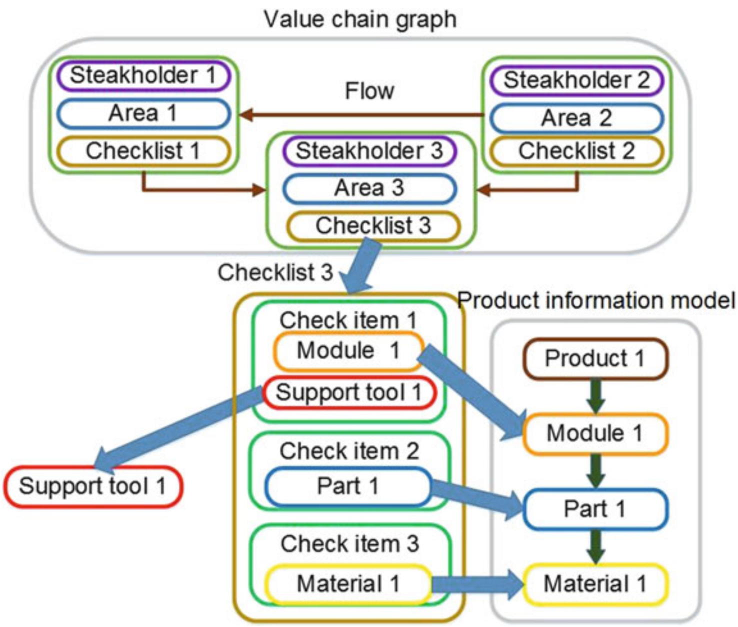

Fig. 5 Construction of LOMmap

influences of the locality on a product and potential candidates of countermeasures to them. The product information model represents the information on the product.

LOMmap is used at the design stage. LOMmap represents one type of product for an area where the product is used. If the supposed area is changed, another LOMmap should be constructed.

6.2 *Value Chain Graph*

The value chain graph represents stakeholders and the areas where the processes of the product life cycle are executed in the form of a graph (see Fig. 6). Each node represents a stakeholder of the product such as a customer and the area where the stakeholder concerns the products, parts, and materials used in the products, and other resources such as money and electricity. Each arc represents the flows of them. Each node and arc in the value chain graph have a checklist.

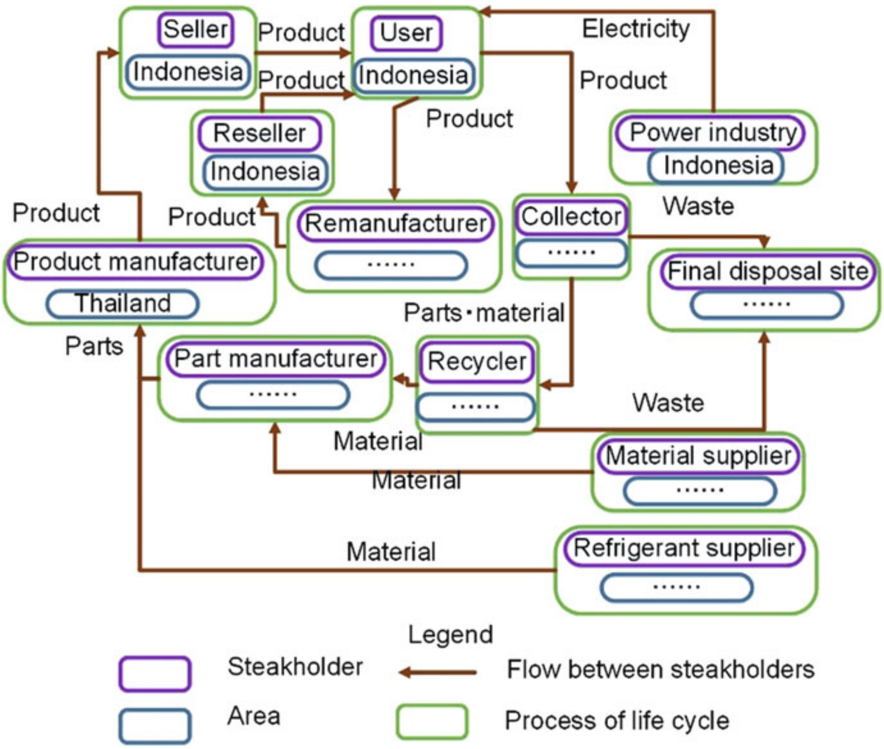

Fig. 6 Value chain graph of the refrigerator for Indonesia (hypothetical)

6.3 Product Information Model

The product information model represents the structure of the product (see Fig. 7). The model consists of a product, modules, parts, and materials of the product. Each element of the model is connected with check items that refer to the component. Each node has the information on attributes of the element.

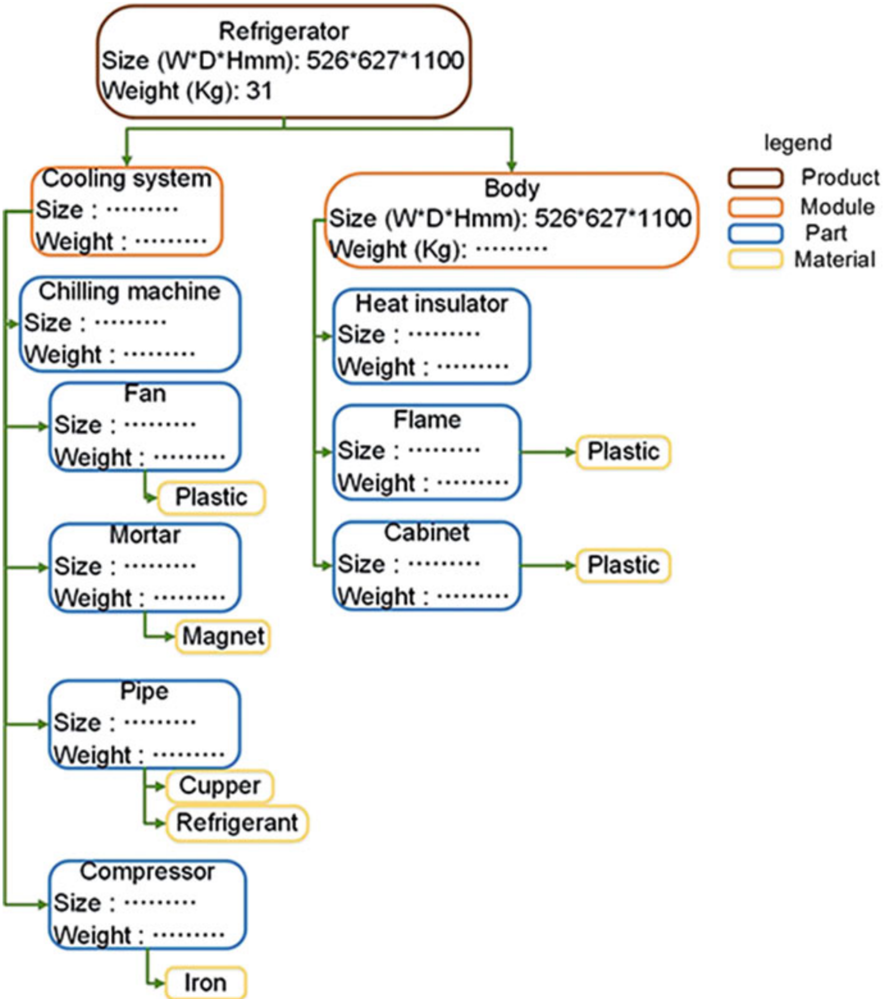

Fig. 7 Product information model of the refrigerator for Indonesia (hypothetical)

6.4 Checklist

A checklist consists of check items. Each check item represents the potential influence and the potential countermeasures and has information described below (see Tables 3 and 4):

- Requirement: This item represents the requirement for the LOMan design.
- Aspect: This item represents categories of the check item, such as law, culture, and economy.
- Targeting area: This item represents the area where the process is executed.
- Element of the value chain graph: This item represents the element of the value chain that has the check item.
- Influence: This item represents the influence of the locality on the product.
- Notes for influence: This item explains the detailed information on the influence.
- Local information: This item represents reference information on the targeting area.
- Element of the product information model: This item represents the elements of the product information model influenced by the locality.
- Support tool: If the designer needs more additional information, a support tool is made and connected with the check item, for example, the tool that shows the prices of the vacuum cleaners in the world.
- Relevance to the product: This item represents the degree of importance of the check item to the product design. This item is represented by a point from 1 to 5. The high number shows the high relevance.
- Idea: This item represents ideas of countermeasures.
- Action: This item represents some detailed solutions for realizing each idea.
- Point of action: This item represents how appropriate the action of the check item is by a point 1–5. The higher point shows higher appropriateness.
- Priority of action: This item represents the priority of the action. This item is calculated by multiplying the relevance to the product and the point of the action.

7 Use of LOMmap

This section describes the process for determining specifications of a product by using LOMmap.

First, the designer determines the product to be designed and the targeting area. Then, experts prepare LOMmap before starting the design process. In this study, we suppose the designer who does not know well the locality of the areas.

Table 3 Example of the check item [1]

Item		Details		
Requirement		Does the refrigerant obey the environmental regesration in the area ?		
Aspect		Law		
Targeting area		Indonesia		
Element of the value chain graph		Product manufacturer		
Influence		The environmental registlation regulates the refrigerant available for the refrigerator.		
Notes for Influence		Regulation on the alternative chlorofluorocarbon for the refrigerator is different in each area. Each alternative chlorofluorocarbon has different global warming potential. There are some flammable alternatives.		
Local information		Using R134a for the refrigerator in not prohibited in Indonesia		
Element of the product information model		Refrigerant		
Support tool		N/A		
Relevance to the product		4		
	Idea	Action	Point of action	Priority of action
1	To use the refrigerant satisfying the minimum requirements for the regulation	To use R134a	3	12
2	To use the more environmentally conscious refrigerant	To use Isobutane	4	16

Table 4 Example of the check item [2]

Item	Details
Requirement	Does the refrigerant obey the environmental regesration in the area ?
Aspect	Law
Targeting area	Indonesia
Element of the value chain graph	Product manufacturer
Influence	The environmental registlation regulates the refrigerant available for the refrigerator.
Notes for Influence	Regulation on the alternative chlorofluorocarbon for the refrigerator is different in each area. Each alternative chlorofluorocarbon has different global warming potential. There are some flammable alternatives.
Local information	Using R134a for the refrigerator in not prohibited in Indonesia
Element of the product information model	Refrigerant
Support tool	N/A
Relevance to the product	4

	Idea	Action	Point of action	Priority of action
1	To use the refrigerant satisfying the minimum requirements for the law	To use R134a	3	12
2	To use the more environmentally conscious refrigerant	To use Isobutane	4	16

7.1 Preparation of LOMmap

LOMmap is made for one type of product for a targeting area. For constructing the LOMmap, we assume the value chain graph is prepared by an expert who knows well about the product life cycle and the areas where each process of the product life cycle is executed. The expert might be a different person from the designer. We assume that the company collects the check items including local information, ideas, and actions for various targeting areas and constructs knowledge base for them. We assume that the designer prepares the product information model by describing the structure of the reference product, which might be a previous generation of the same type of the target product or a competing product model by a competitor.

An expert constructs the LOMmap. The expert connects each check item to an element of the value chain graph and an element of the product information model. The expert is a different person from the designer and the expert of the value chain graph. The expert should know well the product life cycle and the product which is the same type of the target product.

7.2 LOMan Design by Using of LOMmap

We model that the designer uses the LOMmap for designing a new product as follows:

1. With the prepared LOMmap, the designer understands the current product life cycle from the value chain graph.
2. The designer chooses an element of the value chain graph and checks its checklist.
3. In the checklist, the designer checks each check item as follows:

    3.1 The designer understands the requirement, the aspect, the local information, the influence on the product, the notes for the influence, and of the element of the product information model by reading through the check item. If the support tool is connected with the check item, the designer uses the support tool and perceives the additional information. In other words, the designer checks the green items in Table 3.

    3.2 The designer sets the relevance of the check item to the product (i.e., the blue item in Table 3).

    3.3 The designer checks for the ideas and the actions (the green items in Table 4) as the candidates of the solution for the check item. The designer may add new ideas and actions to the check item.

    3.4 The designer determines the point of action for each action. And the LOMmap calculates the priority of actions (the blue items in Table 4).

4. The designer repeats the stages 3.1–3.4 for all elements of the value chain graph.
5. The designer determines the specifications of the product by examining the actions in the order of descending priorities of the actions. According to the specifications, the designer redesigns the target product and modifies the product information model and value chain graph of the redesigned target product.
6. The expert modifies checklists for changes in LOMmap.
7. The designer repeats stages 1–6.

8 Example

We constructed a tiny LOMmap for a refrigerator made for Indonesia. As an example of a check item, we chose the influence of environmental legislation on the choice of the refrigerant described in Sect. 3. We constructed the value chain graph shown in Fig. 6, the product information model shown in Fig. 7, and the check item described in Tables 3 and 4, respectively. In Fig. 7, we described size and weight as attributes. In Tables 3 and 4, the items in green color represent the information for the designer, and those in blue color represent the items that the designer determines.

The designer uses the LOMmap as described in Sect. 7. The designer looks for the information from the green items in Table 3 and sets the relevance to the product. Then, the designer sets the point of actions. As a result, the action "Using Isobutane" has the highest priority of action. The designer determines "to use isobutane" to the specification of the refrigerator.

9 Discussions

By using LOMmap, we succeeded in representing the relationship between locality and its influences on the product life cycle. The value chain graph represents the stakeholders and areas of the product life cycle. The checklists represent influences of the locality on the product life cycle. The product information model represents the structure of the product. LOMmap is for the designer who does not know well the locality of the targeting area where the product is used. By using the LOMmap, the designer understands influences of the locality on the product life cycle and decides the actions for adapting the product to the locality. By executing the action, the specification of the product is expected to become suitable for the locality.

On the other hand, we can point out several issues:

- Some methods for collecting information on the locality influence the product life cycle, and the ideas and actions from the previous products for the checklists are needed.

- Solution candidates designed by the designer may be contradictory with each other. For example, Sect. 8 chooses the isobutane as the refrigerant for the refrigerator. However, isobutane is flammable and this causes the fire risk. The method to assess and solve the contradictory is needed.

10 Conclusion

This paper proposed "Local-Oriented Manufacturing (LOMan)" for achieving social sustainability. LOMan is the concept to focus on the locality at manufacturing and use stages. From case studies to a field survey, we clarified the issues for the LOMan design.

We proposed LOMmap as a method of knowledge representation for supporting a designer in determining specification of a product in the LOMan design and a designer who does not know well the locality of the targeting area.

LOMmap consists of the value chain graph, the product information model, and the checklists. LOMmap represents requirements for the LOMan design in the targeting area by the relationship among these three items. This structure is effective to represent the locality and its influences on the product life cycle.

Future works include:

- Generally speaking, solution candidates designed by the designer may be contradictory with each other. Some support tools for solving these contradictions are needed.
- We are planning to execute a practical case study of the LOMan design and verify advantages and drawbacks of LOMmap.

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